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An investigation of the relationship between inhibitory motor control and low and high trait impulsivity in non-clinical adults

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An Investigation of the Relationship Between Inhibitory Motor Control and Low and High Trait Impulsivity in Non-clinical Adults

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Abstract

Impulsivity is generally thought to refer to rapid, spontaneous and inappropriate behaviour. One causal view of impulsivity is that of executive inhibitory dyscontrol. Inhibitory control requires the suppression of an implicit or explicit response and may be assessed with laboratory behavioural tasks. Executive inhibition includes cognitive inhibition, interference control and behavioural inhibition. Impulsivity is frequently measured using self-report personality-based inventories. Investigations of the relationship between inhibitory control and impulsivity are uncommon. It is further proposed that there is a significant inverse relationship between a self-report measure of impulsivity (the Barratt Impulsiveness Scale) (Patton, Stanford, & Barratt, 1995) and a behavioural measure of motoric inhibitory control (Stop-Signal task) (Logan, 1994). The proposed study will employ a non-clinical cohort to examine this hypothesis.

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Motoric Inhibition: Self-Reported Impulsivity and the Ability to Inhibit Action

Impulsivity is a poorly defined psychological construct. This is principally due to the uncertainty regarding the specific causal components underlying impulsive actions (Enticott & Ogloff, 2006). Consequently many researchers regard impulsivity as a ''multidimensional construct'' (White et al., 1994). However, many researchers agree that the general characteristics of impulsivity include rapid, inappropriate and unplanned behaviours (Dickman, 1990). One possible underlying cause of impulsivity is inhibitory dyscontrol. Inhibitory control requires the successful suppression of an implicit or explicit response (Enticott & Ogloff, 2006).

Inhibition is related to impulsivity (Enticott, Ogloff, & Bradshaw, 2006). The interest in inhibition reflects the identification of impulse control problems in psychopathology, and its heuristic use as a descriptor of problematical behaviour. Although areas of psychology study inhibition and related constructs, there is a lack of integration of personality and cognitive models. This limits an understanding of, and potential clinical applications in this field (Nigg, 2000). For example, Enticott and Ogloff (2006) argue that clinical researchers frequently employ cognitive or personality models without clear justification for their choice of one measurement paradigm over the other. This confusion often results in an assessment of some form of 'global' concept of disinhibition. Furthermore, there are a variety of approaches to the study of inhibition (Chen et al., 1998; Ozonoff, Strayer, McMahon, & Filloux, 1998), but it is not always clear that the same definition of inhibition is applied across studies (Nigg).

Nigg (2000) suggests the term 'executive inhibition' be employed to operationalise the study of inhibition. This view includes an examination of the variables of cognitive inhibition, interference control and behavioural inhibition. Logan, Schachar, and Tannock (1997) argue that executive inhibitory dyscontrol underlies impulsive behaviour. Investigations of the relationship between inhibitory control and impulsivity are unfortunately infrequent (Enticott & Ogloff, 2006), and further work in this area is required.

Impulsivity is typically measured using self-report, personality-based inventories (Enticott et al., 2006). Many impulsivity and inhibitory control studies have been conducted with both clinical and nonclinical populations (Evenden, 1999a). The results from these studies indicate that personality measures of impulsivity do not correlate significantly with measures of inhibitory control (White et al., 1994), suggesting that these concepts might be examining different phenomena. However, more recent studies have reported that personality measures of impulsivity and cognitive inhibition are negatively related to each other (Logan et al., 1997).

One of the most important models in this field is Logan's 'race model' of inhibition (1994). This model proposes that the ability to inhibit a behavioural response depends on the outcome of competing task demands. Logan likens this to a race where the individual's ability to inhibit a behavioural response depends upon the outcome of a race between the independent processes involved in the commencement of, and stopping of, a response. Once the 'go' process is initiated, the 'stop' process must be initiated in time to stop the execution of the 'go' task. Inhibition is measured in terms of the success in achieving inhibitory control and also in terms of measuring the latency of control. Poor inhibitory control can be related to very different components in the stopping process. This can include very fast responding to the prepotent stimulus, responding too slowly to the 'stop' signal, or difficulties initiating the 'stop' process (Badcock et al., 2002). Logan (1985) specifically linked executive control to this process by suggesting that stopping in the inhibition process is triggered in reaction to demands from executive control systems. Logan developed a behavioural laboratory task, the Stop-Signal Paradigm or Stop-Signal Task, specifically to report statistical distributions of observed stopping times (Logan, 1994). Recent studies support the use of the stop-signal paradigm as an effective measure of behavioural inhibition (Enticott et al., 2006).

The available evidence supports the view that participants with high levels of impulsivity are less able to inhibit a prepotent response when compared with participants with low levels of impulsivity (Enticott et al., 2006). Furthermore, high motoric inhibition scores derived from the Barratt Impulsiveness Scale (11^{th} revision; BIS-11) (Patton et al., 1995) are positively and significantly correlated with a reduced ability to inhibit inappropriate responses throughout the stop-signal task (Enticott & Ogloff, 2006; Logan & Cowan, 1984). It is believed that studies of this nature will clarify the relationship between impulsivity and inhibition, and subsequently have applied clinical relevance.

Therefore, this review will consider the concepts of Impulsivity and Inhibition. The specific causal nature of impulsivity will be reviewed. It is proposed that executive inhibitory dyscontrol is one possible causal view of impulsivity. Inhibitory control requires the suppression of an implicit or explicit response. This review will focus on one particular aspect of an executive inhibitory function, that is the concept of behavioural or motoric inhibition. Further it is intended to explore effective methods for measuring both impulsivity and inhibition. The review in conclusion will suggest that the concepts of impulsivity and inhibition are associated.

Impulsivity

There are many theories employed to explain the processes underpinning impulsivity. These include Specious Reward theory, where impulsiveness involves the choice of less rewarding over more rewarding alternatives (Ainslie, 1975), dysfunctional impulsivity, which is thought to be due to poor cognitive retrieval of information from short- and long-term memory (Dickman, 1990), and the biological perspective that emphasises the serotonergic neurotransmitter system (Evenden, 1999a). However, one important causal explanation suggests that impulsivity is the result of inhibitory dyscontrol (Enticott & Ogloff, 2006). Inhibitory dyscontrol is an impairment to the cognitive processes that typically suppress the application of inappropriate responding. It is this lack of control that allows so called impulsive behaviour to occur. Therefore, a more precise definition of impulsivity is associated with the constructs of response or motoric inhibition (Enticott & Ogloff, 2006; Logan, 1985; Logan & Cowan, 1984).

The term 'impulsivity' describes not only impulsive behaviours but a variety of cognitive processes and personality traits that underlie these behaviours (Dickman, 1990). Impulsive behaviour is often acknowledged as a specific personality factor or response style (Enticott & Ogloff, 2006). Within the psychological literature, impulsivity has been variously defined as rapid action without forethought (McMurran, Blair, & Egan, 2002), behaviour without sufficient regard to the potential risks (Patton et al., 1995), and the propensity to act with less thought than others (Dickman; Moeller et al., 2001). Definitions of impulsivity also incorporate subtraits such as risk-taking (Hayaki, Anderson, & Stein, 2006), lack of planning, and making up one's mind too quickly (Eysenck & Eysenck, 1977). Other researchers argue that impulsivity can be disassembled into three distinct components: acting on the spur of the moment (motor activation), not focussing on the task at hand (inattention), failure to plan and think carefully (lack of planning) (Patton et al., 1995). In addition from a personality perspective, impulsivity is also understood to be an important factor in understanding and assessing numerous forms of psychopathology (Whiteside & Lynam, 2001).

From a personality perspective, impulsivity is an important psychological construct (Whiteside & Lynam, 2001). Impulsivity appears in various forms within most major systems of personality. For example, impulsiveness is included as a component of Extraversion in Eysenck's three dimensional view of personality (Eysenck & Eysenck, 1977). Cloninger in his unified biosocial theory of personality includes a superfactor of novelty-seeking, comprising concepts such as, thrill seeking and acting on the spur of the moment (Cloninger, Przybeck, & Svrakic, 1991; Cloninger, Svrakic, & Przybeck, 1993). Finally, Tellegen incorporates a dimension of control, which is contrasted with impulsiveness in his Multidimensional Personality Questionnaire (Rader & Tellegen, 1987; Tellegen, 1982).

Impulsivity is often associated with a range of maladaptive behaviours such as gambling (Blaszczynski, Steel, & McConaghy, 1997), suicide (Paris, 2005), aggression (Bjork, Dougherty, Huang, & Scurlock, 1998) and drug dependency (Allen, Moeller, Rhoades, & Cherek, 1998). Impulsivity is also listed in the DSM-IV-TR (American Psychiatric Association, 2000) as one of many diagnostic criteria for personality disorders, such as Antisocial Personality Disorder (Blaszczynski et al., 1997) and Borderline Personality Disorders (BPD) (Berlin, Rolls, & Iversen, 2005; Paris, 2005).

The DSM-IV-TR (APA, 2000) also includes a variety of descriptions of impulsivity. For example, the diagnostic criteria for Attention-Deficit/Hyperactivity

Disorder (ADHD) impulsivity employs the criterion of problem behaviours such as impatience and interrupting other's conversations (Nigg, Butler, Huang-Pollock, & Henderson, 2002). Impulsivity in this form is regarded as a delayed response rather than a response that should be completely withheld. Conversely, impulsivity in BPD usually involves the use of risky behaviours such as gambling (Berlin et al., 2005; Blaszczynski et al., 1997) and risky sexual behaviour (Paris, 2005). These behaviours are at variance with the behaviours of impulsivity in ADHD where the emphasis is on delayed behaviour rather than completely controlled behaviour (Enticott & Ogloff, 2006). However, the common feature of all these behaviours is that they suggest a deficiency in controlling socially or culturally inappropriate impulses.

Axis I of the DSM-IV-TR also includes impulse-control disorders not elsewhere classified (IC-D NEC). These classifications include disorders such as kleptomania, pyromania and trichotillomania. These are all disorders that emphasise deficient impulse control, or the inability to suppress inappropriate actions (Arehart-Treichel, 2003; Bayle et al., 2003; Chamberlain et al., 2006). In these instances the person is responding to a heightened state of arousal, and the behaviour is understood to gratify and reduce internal tension (Paris, 2005).

Despite the ambiguity surrounding a comprehensive definition of impulsivity, there is still agreement on the broad features of impulsive behaviour. Impulsivity is generally expressed as rapid, unplanned, excessive, and maladaptive conduct (Dickman, 1990; Enticott & Ogloff, 2006; Moeller et al., 2001).

Measurement of Impulsivity

There are many different methods used to quantify impulsivity (Dougherty, Mathias, Marsh, & Jagar, 2005). These include retrospective self-report ratings (BIS-11) (Patton et al., 1995), neurobiological measurement (Event-related Cortical

Potentials) (Marinkovic, Halgren, Klopp, & Maltzman, 2000) or less commonly by means of a behavioural observation/report (Enticott & Ogloff, 2006). The evidence suggest that laboratory and self-report measurement are the principal methods employed.

There is debate whether self-report or laboratory-based measurement represents the optimal method for measuring impulsivity. Many researches employ self-report measures and believe that there are aspects of impulsivity cognitively accessible to an individual (Patton et al., 1995). Other researchers employ laboratory measures and argue that impulsivity can be measured in an experimental setting using behavioural observations and inference (Bjork et al., 1998; Cherek, Moeller, Dougherty, & Rhoades, 1997; Enticott et al., 2006).

One of the most popular self-report measures of impulsivity is the BIS (Enticott et al., 2006). Recently, the BIS was comprehensively revised in order to identify a set of impulsiveness items that were orthogonal to a set of anxiety items and to define impulsiveness within the structure of related personality traits such as Eysenck's Extraversion dimension (Eysenck, 1984).

Critics suggest that self-report measures, such as the BIS, fail to consider the concept of inhibitory control (Dougherty et al., 2005). Furthermore, self-report measures are entirely dependent on respondent veracity, and are not suitable for repeated use (Moeller et al., 2001). Also, impulsive individuals typically return incorrect responses to questions that require them to review their past behaviour (Cherek et al., 1997). For example, a prisoner cohort (generally regarded as impulsive), do in fact return higher impulsivity scores on self-report measures such as the BIS, when compared to nonclinical populations (Bjork et al., 1998; Cherek et al., 1997).

There are three broad categories of laboratory procedures used to measure impulsivity. These include: response-disinhibition/attentional; reward-choice; and punished and/or extinction paradigms (Moeller et al., 2001). Response-disinhibition/attentional models such as the Stop-Signal Paradigm (Logan, 1994) measure an individual's ability to inhibit an already initiated response. Reward-directed procedures such as the Two Choice or Single Key Impulsivity Paradigm assess tolerance for delayed rewards (Dougherty et al., 2003; Dougherty et al., 2004; Marsh et al., 2002). Punished and/or extinction models such as the Passive-Avoidance Paradigm measure a participant's propensity to either approach or to avoid punishment/reward stimuli (Dougherty et al., 2004; Evenden, 1999a, 1999b).

Laboratory based inhibitory control tasks are considered objective tests of impulsivity (Enticott et al., 2006). This is because they provide a performance-based measure which is free of participant bias. Laboratory tasks are also sensitive to short-term state-dependent fluctuations. Therefore, laboratory behavioural measurement can account for some of the distinctive variance characteristics that self-report measures are not able to report (Dougherty et al., 2005).

The principal limitation of laboratory tasks includes their failure to assess the social characteristics of impulsivity (Moeller et al., 2001). Furthermore, they are typically conducted in relatively neutral environments and are therefore less affected by external stressors. Stressors may increase an individual's autonomic arousal which is thought to increase the likelihood of impulsive behaviour occurring (Enticott & Ogloff, 2006). Therefore due to the multifaceted nature of impulsivity (Nigg, 2000) it may be prudent to employ a combination of laboratory and self-report measures as this may ensure a more comprehensive assessment of impulsive behaviour (Dougherty et al., 2005; Enticott et al., 2006).

The impulsivity literature generally supports the view that the behavioural expressions of impulsivity include rapid, excessive and unplanned behaviour (Enticott & Ogloff, 2006). However, the underlying causal nature of impulsivity remains elusive. Many researchers believe that impulsive behaviour is able to be controlled, however, when under the influence of stressful stimuli, impulsive behaviour is more likely to occur (Nigg, 2000). While acknowledging that impulsivity may result from a composite of genetic, neurobiological (Chambers & Potenza, 2003; Evenden, 1999b), and environmental factors (Kreek, Nielsen, Butelman, & LaForge, 2005; Sherman, Iacono, & McGue, 1997) this review is primarily concerned with the underlying cognitive mechanisms that control or permit behavioural expressions of impulsivity.

The most common view from the cognitive perspective of impulsivity suggests that it occurs when the individual acts without forethought. It is thought that impulsive behaviour occurs without regard to its consequences (Dickman, 1990; Smillie & Jackson, 2006). It is also thought that the inhibitory processes are able to be consciously controlled (Enticott & Ogloff, 2006). An alternative view is that impulsive behaviour results from making up one's mind too quickly (Arce & Santisteban, 2006; Eysenck & Eysenck, 1977). This view suggests that an impulsive individual arrives at a decision too quickly, and that they are unable to change their decision. However, it remains unclear if this occurs because of their failure to consider all viable alternatives or whether they are incapable of incorporating all relevant information into the decision-making process. A final view is that impulsivity is the result of an inability to delay gratification (Ainslie, 1975; White et al., 1994). This occurs when an individual is forced to choose between the receipt of an immediate small reward, over a future larger reward (Cherek et al., 1997;

Rodriguez, Mischel, & Shoda, 1989). According to Enticott and Ogloff (2006) the inability to delay gratification is a well-defined and operationalised causal component of impulsive behaviour.

Despite this, the cognitive accounts of impulsivity are too imprecise to satisfactorily operate as a comprehensive scientific model of impulsivity. In contrast, inhibitory dyscontrol has promise as a scientific theory (Enticott & Ogloff, 2006).

Inhibition

An alternative view of impulsivity suggests that it arises from the impairment of executive inhibitory processes. These processes typically suppress improper behavioural responses (Boucher, Palmeri, Logan, & Schall, 2007; Logan et al., 1997). The failure to suppress inappropriate behavioural responses can be understood to provide an explanation of both how and why impulsive individuals execute contextually inappropriate behaviours (Enticott & Ogloff, 2006).

Dysfunctional inhibition is also affected in a diversity of psychological disorders that include ADHD (Berlin, Bohlin, Nyberg, & Janols, 2004), anxiety (van Brakel, Muris, Bogels, & Thomassen, 2006), general mood disorders (Campbell-Sills, Liverant, & Brown, 2004), alcoholism and substance abuse (Nigg et al., 2006), antisocial behaviour (Newman, Wallace, Schmitt, & Arnett, 1997), schizophrenia (Bellgrove et al., 2006), obsessive–compulsive disorder and trichotillomania (Chamberlain et al., 2006), and Tourette's syndrome (Ozonoff et al., 1998). Therefore, the study of inhibition has important clinical relevance as it is a feature of many psychological disorders. This component of the review will suggest that reduced motoric inhibition is associated with personality-based impulsivity.

The most comprehensive account of inhibitory control is offered by Nigg (2000). Nigg has proposed an integrated model of inhibition which emphasises the importance of both cognitive and personality variables in understanding behavioural inhibition. The three primary classes of inhibition are: motivational inhibition; automatic inhibition of attention and executive inhibition effects. This model has also been adopted by researchers as a sound base from which to further conceptualise inhibitory control (Enticott & Ogloff, 2006).

Nigg (2000) argues that the motivational inhibition effects originate from within the motivational-based models of temperament and personality. These processes are related to the cognitive models which underline emotionally relevant stimuli such as anxiety (e.g., go/no-go task) (Newman, Patterson, & Kosson, 1987) and the focus is on behaviour and cognition. Here motivation refers to a "bottom-up" (limbic to cortical) disruption of ongoing behaviour or the suppression of a behavioural response to fear or anxiety (Nigg). However it is still unclear whether these types of motivational inhibition represent controlled or automatic processes.

Executive systems can effortfully override the fear/anxiety-based inhibition systems (Nigg, 2000). Some researchers have shown that there is a distinction between executive and motivational systems (Mezzacappa, Kindlon, Saul, & Earls, 1998; Rothbart & Ahadi, 1994), whereas others argue that there are at least two motivational types of inhibition that respond to different incentive systems (Asendorpf, 1990). They may be accessed by means of executive tasks with attached motivational conditions (Newman et al., 1987; Williams, Mathews, & MacLeod, 1996) or by some other automatic attentional process (Nigg, 2000).

Automatic inhibitory processes are related to attentional procedures. These processes are typically seen in disorders such as anxiety (Avila & Parcet, 2002; Berns et al., 2006) and the inattentive subtype of ADHD (Aman, Roberts, & Pennington, 1998). The connection between personality and automatic inhibition is unclear, although higher order personality traits may be related to automatic inhibition (Nigg et al., 2002). For example, Wallace and Newman (1997) argue that Neuroticism is related to the automatic orientation of attention via the subcortical structures including the midbrain. These areas are known to affect both attention and motivation. Others, such as Derryberry and Rothbart (1997) suggest that the posterior orienting system is implicated in orienting attention, particularly when both anxiety and fear are present. The role of anxiety systems in automatically filtering attention is evidenced via the emotional Stroop (Egloff & Hock, 2001) and these studies show that Neuroticism may be implicated in automatic attentional allocation (Nigg, 2000). While acknowledging the role of automatic inhibitory processes, the focus of this review is on controlled inhibition. Enticott et al. (2006) argue that controlled inhibition is more suitable to laboratory-based assessment .

Executive inhibition controls are processes that either intentionally control or suppress a response. According to Nigg's (2000) model there are four subtypes of executive inhibition controls: interference control, which modulate interference from competing resources or stimuli; cognitive inhibition controls, which suppress irrelevant ideation to guard working memory/attention; behavioural inhibition controls, which restrain prepotent responses; and oculomotor controls, which effortfully suppress the automatic saccade (Nigg, 2000).

Nigg (2000) argues that these executive processes form a component of the Constraint/Conscientiousness dimension. Specifically, they have been linked to Rothbart's (1994) effortful control trait. Effortful control is related to attentional persistence and is suggested to facilitate the development of the personality trait of constraint (Clark, Watson, & Mineka, 1994). Effortful control is explicitly related to Posner's attentional model (Posner & Rothbart, 2000). It is mediated by the frontal executive systems, particularly the anterior attentional system within the anterior cingulate cortex (Luu & Posner, 2003) and it also regulates the development and expression of other personality dimensions (Nigg, 2000).

Several theoretical proposals have attempted to relate an individual differences approach to cognitive or psychobiological models (Logan et al., 1997; Rothbart & Ahadi, 1994; Wallace & Newman, 1997). Others suggest that there are common factors among cognitive and emotional regulatory systems (Derryberry & Rothbart, 1997). However, the challenge remains for researchers to determine valid and reliable shared measures and to provide additional supportive evidence of the proposed distinctions (e.g., motivational vs. executive systems) (Nigg, 2000; White et al., 1994).

Researchers such as Nigg (2000) believe that oculomotor recordings constitute a field of their own and should not necessarily be categorised as an executive function. On this basis oculomotor effects are excluded from this review. It is also unclear whether inhibitory processes of focused attention are controlled or automatic, and if inhibition is actually the underlying process (Milliken, Joordens, Merikle, & Seiffert, 1998).

Interference control is pertinent to both motor control and working memory (Nigg, 2000). Interference control refers to each of the following: the suppression of a response when it conflicts with the primary response; the suppression of a distracting stimulus that may slow the primary response; the control of an internal stimulus that impedes the current operation in working memory. Experimental tasks that are associated with interference control procedures include priming and "flanker" tasks (Gratton, Coles, & Donchin, 1992).

Interference control is also relevant to the inhibition of unwanted thoughts that interfere with working memory. The directed forgetting paradigm is widely used in the assessment of interference control, specifically with the inhibition of memory processes (Hourihan & Taylor, 2006). Result from these studies typically show that participants recall "remember" words more accurately than "forget" words. However, scores of recognition memory are similar for both lists. These studies support the existence of a cognitive inhibition mechanism which suppresses information from working memory but not recognition memory (Wilson & Kipp, 1998; Wilson, Kipp, & Chapman, 2003; Wilson, Kipp, & Daniels, 2003). This idea is particularly relevant to disorders such as BPD (Korfine & Hooley, 2000), Post Traumatic Stress Disorder (Cottencin et al., 2006) and general trauma (DePrince & Freyd, 2004).

Motoric inhibition requires the effortful control of a primary motor responding to changing contextual signals (Chamberlain et al., 2006). Traditionally researchers have employed the go/no-go task to investigate motoric inhibition (e.g., Casey et al., 1997; Gondo et al., 2000; Newman et al., 1987; Schulz et al., 2007). Computerised motoric inhibition tasks require participants to "go" (e.g., press a key on the keyboard) to a frequent stimulus (e.g., the letter "A") when it appears, and not to respond ("no-go") to an infrequent stimulus (e.g., the letter "B"). Therefore, the go/no-go task necessitates the inhibition of a prepotent response (Enticott et al., 2006).

Measurement of Inhibition

Among the experimental paradigms that have been developed to measure aspects of inhibition including flanker tasks and directed forgetting paradigms, contemporary researchers (Enticott & Ogloff, 2006; Nigg, 2000) argue that the stop-signal paradigm developed by Logan and colleagues (Logan, 1994; Logan & Cowan, 1984) is a more theoretically sound paradigm for the measurement of motoric inhibition. The stop-signal task is a forced choice paradigm. Participants are required to monitor a computer display and to press one of two keys as quickly as possible depending on whether an 'X' or an 'O' appears on screen. This rapid key press response becomes the prepotent or dominant 'go' response. On a minority of trials (usually 25%), a tone sounds and the participant must inhibit their responding. The delay between the onset of the tone presentations is varied and sometimes it is easier to stop. Studies have shown that if the tone is presented immediately prior to the appearance of the target then it is easier to stop compared to when the tone is presented after a delay (Enticott et al., 2006; Logan, 1994). This suggests that the task requires inhibition of a prepotent motor response. Based on measurement criteria such as response time, stopping success, and stop-signal timing, the speed of the stop process can be calculated. Failure to inhibit a response can be due either to a fast 'go' process or a slow 'stop' process (Logan, 1985, 1994; Logan & Cowan, 1984).

Logan's theory conceptualised the stop-signal paradigm as relating to the cessation of thought and action (Logan & Cowan, 1984). This conceptualisation incorporates aspects of both cognition (thought) and motor inhibition (action) in response to changing stimuli. For example, the participant needs to modify their response to new information after they have inhibited the current thought or action. Logan (1985) specifically linked executive control to this process.

In a later study, Logan (1994) proposed a 'race model' theory of inhibition (Badcock et al., 2002). In this model Logan suggests that the ability to inhibit a behavioural response depends on the outcome of competing task demands. If the 'go' process is completed prior to the onset of a stop process, then the 'stop' process will not occur. If the 'stop' process commences prior to the conclusion of the 'go' process then the 'go' process will not occur. A fundamental assumption of this model is that the 'go' and 'stop' processes are independent, however, the race model is not a process model as such (Nigg, 2000) but rather a model that reports statistical distributions of observed stopping times (Logan, 1994).

Of particular interest is a recent study conducted by Enticott, Ogloff, and Bradshaw (2006). This research is an often referenced examination of the relationship of impulsivity and inhibition using the BIS-11 (Patton et al., 1995). The researchers employed four behavioural paradigms to measure inhibitory control (motor inhibition, stop-signal, Stroop, and negative priming). The experimental cohort consisted of university students ($N = 31$; age range: 19–51). They reported significant positive correlations among Stroop and non-planning ($r = .56$) and self-reported impulsiveness ($r = .86$); motor disinhibition and non-planning impulsiveness ($r = .38$). However, they did not report a significant correlation between impulsivity and Stop-Signal Reaction Time (SSRT). However, their findings returned evidence suggesting an association between impulsivity and some measures of inhibitory dyscontrol. These include motor and response disinhibition. These findings provide some support for Nigg's (2000) model of inhibition (Enticott et al., 2006)

There are a number of potential limitations with the Enticott et al. (2006) study. First, they used a relatively small number of participants ($N = 31$). This may have limited the statistical power of their findings. Second, the study employed a Stop-Signal task that presented visual stimuli to either the left or right visual fields. Their methodology did not control for participant handedness. Handedness is associated with hemispherical lateralisation (Sperry, 1974), and the presentation of visual stimuli to left or right visual fields, in the context of their study, represents a potential methodological flaw in their design. For example, a recent stop-signal study by Bellgrove (2006) reported a lateralised deficit in response inhibition for the left hand. Yet there were no differences noted for right-handed inhibitory control. Bellgrove concluded that the results indicate a specific lateralized impairment of response inhibition in some participants in a stop-signal task.

Summary

This review has considered similarities and differences between Impulsivity and Inhibition. Definitions of impulsivity include characteristics such as rapid, unplanned and maladaptive behaviour (Moeller et al., 2001). Impulsive behaviours are noted in both non-clinical (Dickman, 1990) and clinical populations (Allen et al., 1998; Paris, 2005), and are normally measured using self-report personality ratings such as the BIS (Patton et al., 1995). The behavioural expressions of impulsiveness vary between impatience (Nigg et al., 2002) and forceful aggression (Bjork et al., 1998). It is argued (Nigg, 2000; Enticott & Ogloff, 2006) that the elucidation of impulsivity is limited due to the uncertainty of the actual cognitive basis of impulsive behaviour. In the current study it will be hypothesised that impulsivity is associated with inhibitory dyscontrol (Boucher et al., 2007; Enticott & Ogloff, 2006).

Inhibitory control requires the suppression of inappropriate responses (Boucher et al., 2007; Logan et al., 1997). Neurological studies implicate the involvement of neural systems such as the orbitofrontal cortex (Berlin et al., 2005; Fassbender et al., 2004), and anterior cingulate cortex (Luu & Posner, 2003) in inhibitory processing. Inhibition paradigms vary and incorporate both personality and cognitive features (Nigg, 2000). Measurement paradigms are usually related to a specific class of inhibition, for example the stop-signal task with motoric inhibition (Enticott et al., 2006). It is not known if the various paradigms measure identical processes in different contexts, or different processes altogether. Furthermore, it remains unclear if these paradigms measure automatic or controlled inhibition (Schneider & Shiffrin, 1977).

According to Nigg (2000) there are four types of executive inhibitory process that intentionally control or suppress maladaptive responses. Central to the proposed study is the concept of behavioural inhibition, as this is believed to suppress prepotent responses (Logan & Cowan, 1984; Newman et al., 1997; Nigg et al., 2002). Behavioural inhibition is a key feature of various forms of psychopathology, such as ADHD (Berlin et al., 2004; Nigg et al., 2002). Behavioural controls provide a timing delay in which executive functions can then function efficiently (Logan, 1985).

Presently, the relationship between impulsivity and inhibition remains unclear. Whilst, impulsivity is frequently measured via self-report methods, inhibition is normally examined through objective laboratory-based control tasks. Laboratory-based tasks can provide results that are potentially free of participant bias (Enticott et al., 2006). However, one limitation of laboratory-based tasks is that they might not fully explain environmental factors thought to facilitate impulsivity, for example autonomic arousal (Egloff & Hock, 2001). Under these circumstances self-report measures enjoy greater validity (Dougherty et al., 2005; Moeller et al., 2001). Therefore an important theoretical question is whether there is a significant correlation among scores using a combination of these methods (Enticott et al., 2006).

Studies indicate that some personality measures of impulsivity correlate well, albeit weakly with measures of inhibitory control (Enticott et al., 2006; White et al., 1994). It is unclear whether the lack of a stronger correlation signifies the measurement of relatively independent constructs, or simply reflects variability within measurement paradigms. Conversely, a number of studies suggest that inhibition and personality based impulsivity may be negatively related (Logan et al., 1997). These inconsistencies are possibly due to the nature of the measures employed (Enticott et al., 2006). Future research is needed to further elucidate the relationship of measures of impulsivity and levels of inhibition.

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High and Low Trait Impulsivity in Non-clinical Adults and Motor Inhibition Control

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High and Low Trait Impulsivity in Non-clinical Adults and Motor Inhibition Control

Abstract

Inhibitory deficits have frequently been reported in clinical groups. It is unknown whether the same deficit underlies the personality trait of impulsivity in non-clinical adult populations. The current study investigated whether there is an association between self-reported trait impulsivity and inhibitory motor control. The stop-signal task was employed to examine the inhibitory performance of non-clinical adults. Participants were allocated to a high or low impulsivity group on the basis of their Barratt Impulsiveness Scale (BIS-11) scores. Those participants scoring in the top 25% ($n = 18$) and bottom 25% ($n = 18$) on the BIS-11, from a sample of 73, were allocated to the high or low impulsive groups respectively. The stop-signal task employed a visual choice reaction time 'go' task and participants attempted to inhibit their responses to the 'go' task when an auditory 'stop' signal was heard. The findings indicate that there was no deficit in motor inhibition found for high-impulsives, nor did the groups differ on either the speed of their response, or the probability of inhibiting their response, to a 'stop' signal. However, there was a weak but non-significant correlation found supporting an association between motor impulsivity and stop-signal reaction time ($r = .35$, $p = .06$). In conclusion, the current study found only minor evidence that impulsivity in a non-clinical adult cohort is associated with poor inhibitory motor control.

Key words: trait impulsivity, motor inhibition, Stop-signal

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High and Low Trait Impulsivity in Non-clinical Adults and Motor Inhibition Control

Introduction

Impulsivity is generally characterised by rapid, inappropriate and unplanned behaviours (Dickman, 1990). It has been alternatively defined as rapid action without forethought (McMurran, Blair, & Egan, 2002), behaviour without sufficient regard to the potential risks (Patton, Stanford, & Barratt, 1995), and the propensity to act with less thought than others (Moeller et al., 2001). Definitions of impulsivity also incorporate subtraits such as risk-taking (Hayaki, Anderson, & Stein, 2006), lack of planning, and making up one's mind too quickly (Eysenck & Eysenck, 1977). Impulsivity is often associated with a range of maladaptive behaviours such as gambling (Blaszczynski, Steel, & McConaghy, 1997), suicide (Paris, 2005), aggression (Bjork, Dougherty, Huang, & Scurlock, 1998; Cherek, Moeller, Dougherty, & Rhoades, 1997), and drug dependency (Allen, Moeller, Rhoades, & Cherek, 1998). Impulsivity is also listed in the DSM-IV-TR (American Psychiatric Association, 2000) as one of many diagnostic criteria for personality disorders, such as Antisocial Personality Disorder (Blaszczynski et al., 1997), Attention-Deficit/Hyperactivity Disorder (ADHD) (Nigg, Butler, Huang-Pollock, & Henderson, 2002) and Borderline Personality Disorder (BPD) (Berlin, Rolls, & Iversen, 2005; Paris, 2005).

The personality trait of impulsivity is typically measured using self-report questionnaires, such as the Barratt Impulsiveness Scale (11th revision; BIS-11) (Patton et al., 1995) (see Appendix A). However, self-report questionnaires are dependent upon subjective responses and may be influenced by self-reporting biases (Enticott, Ogloff, & Bradshaw, 2006). Therefore, other researchers have employed laboratory-based tests, which are thought to more objectively measure impulsivity

(Dougherty, Mathias, Marsh, & Jagar, 2005). Here, impulsivity has been operationalised as an inability to inhibit a cognitive or behavioural response (Logan, Schachar, & Tannock, 1997).

Stop-Signal Paradigm

The stop-signal paradigm is a laboratory-based task suitable for objectively assessing response or motor inhibition that is thought to underlie impulsivity (Badcock, Michie, Johnson, & Combrink, 2002). Specifically, the stop-signal task allows measurement of the effectiveness and latency of the inhibition process in stopping impulsive and inappropriate responses (Bellgrove, Hester, & Garavan, 2004; Enticott et al., 2006; Logan, 1994). The stop-signal task is a forced-choice paradigm (Badcock et al., 2002). Participants are required to perform a binary choice reaction time task and to inhibit a prepotent or dominant 'go' response when the stop-signal is presented. This stop-signal is randomly presented on a minority of trials (usually 25%). Performance in the stop-signal task is accounted for by Logan's Race Model (Logan, 1994; Logan & Cowan, 1984; Logan, Cowan, & Davis, 1984), which suggests that the ability to inhibit a response depends upon the speed and outcome of the 'go' and 'stop' responses. The speed of the inhibition response or Stop-signal Reaction Time (SSRT) is calculated by estimating the relative finishing times of the two responses. It has been reported that SSRT is longer in children (Oosterlan, Logan, & Sergeant, 1998), and adults with ADHD (Murphy, 2002) compared to healthy controls. These findings are supportive of the work of Nigg (2001) who proposes that poor inhibitory motor control is a principal feature of impulsivity and also Barkley (1997) who posits that inhibitory control affords a delay wherein executive functions can control effectively.

Other studies have reported associations among impulsivity scores and inhibitory motor control, and that higher impulsivity scores were related to longer SSRTs (Avila & Parcet, 2001; Logan et al., 1997; Marsh et al., 2002). These studies employed designs where participants were separated into high-impulsive (above median) and low-impulsive (below median) groups (Lijffijt et al., 2004). Rapid and inaccurate responding to the choice (go) Reaction Time (RT) task are also considered as indicators of impulsivity (Dimoska & Johnstone, 2007).

The relationship between behavioural and laboratory measures of impulsivity is supported by numerous studies (Arehart-Treichel, 2003; Avila & Parcet, 1997; Berlin et al., 2005; Bjork et al., 1998; Bjork et al., 2000). These studies have consistently reported that impulsivity is characterised by poor inhibitory control in clinical populations (Evenden, 1999; Newman, Wallace, Schmitt, & Arnett, 1997; Summerfeldt et al., 2004) and in impulse control disorders, such as gambling (Blaszczynski et al., 1997) and aggression (Cherek et al., 1997). However, it is less apparent whether a deficit in response inhibition underlies impulsivity in a non-clinical population. Relevant studies that have employed non-clinical cohorts have reported higher scores on impulsiveness questionnaires relating to longer SSRTs (Logan et al., 1997), larger inattention (Avila & Parcet, 1997), and the reduced probability of inhibition (Marsh et al., 2002). However, correlational studies have not found a consistent relationship between impulsiveness and SSRT measures (Cheung, Mitsis, & Halperin, 2004; Enticott et al., 2006) or inhibition probability (Fallgatter & Herrmann, 2001; Harmon-Jones, Barratt, & Wigg, 1997; Horn et al., 2003).

Recently Enticott, Ogloff, and Bradshaw (2006) conducted a correlational study using an Australian university student cohort ($N = 31$; age range: 19–51). Their study examined the relationship of impulsivity measured by the BIS-11 (Patton et al.,

1995) and four behavioural paradigms employed to measure inhibitory control (motor inhibition, stop-signal, Stroop, and negative priming). They reported significant positive correlations among Stroop and non-planning (*r* = .56) and self-reported impulsiveness (*r* = .86); motor disinhibition and non-planning impulsiveness (*r* = .38). However, they did not report a significant correlation between impulsivity and SSRT (*r* = -.03), although they did find evidence suggesting an association between impulsivity and motor disinhibition (*r* = -.17). These findings provide limited support for Nigg's (2000) model of inhibition (Enticott et al., 2006). The Enticott et al. (2006) employed a relatively small number of participants (*N* = 31) and this may have limited the statistical power of their findings.

Recent non-correlational studies have employed non-clinical cohorts separated in to low and high impulsivity groups (Dimoska & Johnstone, 2007; Lijffijt et al., 2004). These studies have been based on a study conducted by Rodriguez-Fornells, Lorenzo-Seva, and Andres-Pueyo (2002), who suggested that comparisons of high and low impulsive groups may represent a more sensitive analysis of impulsivity compared with previous correlational studies (Logan et al., 1997). Rodriguez-Fornells et al. (2002) had allocated participants to high-impulsive or low-impulsive groups based on scores on the impulsivity subscale of the Eysenck Personality Inventory (Eysenck & Eysenck, 1964). They reported that SSRT was not significantly different between groups. However, it was suggested by Lijffijt et al. (2004) that these non-significant findings may be due to the small sample size employed (*N* = 20) and the normal variation of SSRT within a given population. Therefore, other researchers (Dimoska & Johnstone, 2007; Lijffijt et al., 2004) have since extended the Rodriguez-Fornell study but have not been able to report significant differences between high and low groups on SSRT.

The Current Study

The current study reappraised the question of whether high-impulsive people suffer from deficient inhibitory motor control compared to low-impulsive individuals. To address this question, the current experiment was designed so that non-clinical adults were allocated to low and high-impulsivity groups, prior to performing a stop-signal task. The current study was both an extension and combination of the recent studies conducted by Enticott et al. (2006) and Rodriguez-Fornells et al. (2002).

A larger participant sample was employed in order to increase the statistical power of the study. The stop-signal task was designed to employ a visual 'go' cue presented to a central visual position on the computer screen and an audio stimulus was used for the 'stop' condition. The Rodriguez-Fornells et al. (2002) study was extended by employing the BIS-11 to measure impulsivity rather than the Eysenck Personality Inventory (Eysenck & Eysenck, 1964). It was thought that the BIS-11 may provide a more parsimonious self-report measure of impulsivity. Also, increasing the number of participants (n = 36) may increase the statistical power of the study and account for the variability in participant performance on the stop-signal task.

In summary, the primary aim of the current study was to examine whether self-reported trait impulsivity, assessed with the BIS-11, is associated with a deficit in response or motor inhibition, as measured by the stop-signal task, in a non-clinical cohort. According to the race model of inhibitory control (Logan, 1985, 1994; Logan & Cowan, 1984) the stop-signal task will return two distinct measures representing response inhibition, SSRTs and the probability of inhibition (POI). It was expected that relative to the low-impulsive group, high-impulsives would show a deficit in motor inhibition which should manifest as a longer (slower) SSRT and reduced inhibition probability, or both (Logan, 1985, 1994).

Furthermore, considering that past studies have been unable to show significant support of an impulsivity/inhibition association by comparing overall BIS-11 scores and SSRT, the present study investigated the relationship between the motor inhibition and motor impulsiveness subscales of the BIS-11 with SSRT. It was suggested that the two motor subscales may more adequately represent the form of inhibition measured by the stop-signal task. Should an association between inhibition and impulsivity be found in a non-clinical cohort, then this may function as a legitimate model for poor inhibitory motor control.

Method

Participants

A total of seventy three adults participated in the study (19 male, 54 female; age range 18 –56 years, *M* = 32.1, *SD* = 11.76). The participants were recruited from a pool of volunteers registered at the Edith Cowan University, School of Psychology, or other persons known to the researcher. All participants reported they had normal or corrected-to-normal vision, no impairments of hearing, and were English first language speakers. There were 63 right-handed participants and 10 left-handed participants. Those participants who obtained a score on the BIS-11 placing them in the top or bottom 24.67% of scores were chosen to comprise the high and low impulsivity groups (*n* = 18 in each group; 6 male and 12 females in the high group and 2 male and 16 females in the low group). All participants were exposed to all facets of the study.

Materials

Barratt impulsiveness scale.

The Barratt Impulsiveness Scale, Version 11 (BIS-11) (Patton et al., 1995) is a 30-item self-report questionnaire designed to measure impulsiveness. The structure of the questionnaire permits the evaluation of six first-order factors (attention, motor, self-control, cognitive complexity, perseverance, cognitive instability) and three second-order factors (attentional impulsiveness, motor impulsiveness and nonplanning impulsiveness). An overall score is calculated by totalling either the first or second-order factors. The items are scored on a four point scale (Rarely/Never [1], Occasionally [2], Often [3], or Almost Always/Always [4]), with several items reverse coded. A higher overall score indicates higher measures of impulsiveness (Enticott et al., 2006). The BIS-11 was used to provide a parsimonious self-assessment of impulsivity.

Stop-signal task.

The stop-signal task consisted of a primary binary-choice (Go) RT task where visual stimuli, consisting of the upper case letters 'X' or 'O', were presented sequentially in the centre of a computer monitor for 1000 ms, each with a probability of 50%. Each go-task stimulus was preceded by a fixation point. The audio signal was a 100 ms 1000 Hz tone generated by the computer and presented through the computer speaker. The audio signal was presented randomly on 25% of trials. The tone acted as a stop-signal, instructing participants to inhibit their responses to the primary 'go' task. Responses were obtained by either a left or right hand button press on the computer keyboard in response to the presented stimuli, 'X' ('Z' key –left hand) and 'O' ('/' key – right hand).

Procedure

The stop-signal testing was administered over a of four week period. The initial testing of nearly 40 third-year Psychology students, took place in a computer laboratory, where participants simultaneously performed the stop-signal task on desktop computers. Further, participants were needed for the study and these were recruited from family and friends of the researcher. The remaining 33 participants performed the stop-signal task independently in a quiet room, using either a laptop or desktop computer. However, prior to commencement of the testing, participants provided written consent and each participant was assigned a unique 5-digit identifier.

First, participants were asked to write their identifier code on the top page of the questionnaire. Participants then completed the BIS-11. At the completion of the questionnaire phase, the participant was required to input their unique 5-digit into the stop-signal program. The stop-signal task began with the reading of the experimental instructions to the participant (see Appendix B). The task instructions were also presented on the computer screen enabling the participants to read the instructions at the same time as the researcher read them aloud. Following the reading of the instructions, the task commenced when either of the response keys were pressed. The first stage of the trial was a practice phase. At the completion of the practice phase an additional set of instructions were read.

The race model of inhibition predicts that probability of inhibition is partly dependent upon the variability and the speed of the 'go' process (Logan, 1994). To control experimentally for individual variations in 'go' processing speed, stop-signals were presented at varying delays relative to the participant's expected response or in other words their mean reaction time (MRT) (Badcock et al., 2002). Therefore, six levels of Stop-Signal Delay (SSD) were incorporated in the repeated measures study. The SSD was calculated from each participant's mean reaction time to the primary task: i.e. SSD = (MRT – 0)ms, (MRT – 100)ms, (MRT – 200)ms, (MRT – 300)ms, (MRT – 400)ms and MRT – 500)ms. For example, an SSD calculated by the formula (MRT - 0)ms, corresponded to a stop-signal presentation at approximately the time that the response to the primary task would be expected and therefore the participant is unlikely to be able to stop. Each participant's MRT was initially calculated during the practice block and then used to set the delay for the first response task. Response latencies calculated in the first testing block were then utilised to set the delay in the second block of response testing and so forth. The stop-signal was then presented twice at each of the six delay points per trial block (total of 18 trials for each SSD). Each stop-signal occurred equally frequently with each stimuli. All trials were randomised within blocks so that the sequence of primary task stimuli, stop-signals and stop-signal delays were presented randomly.

Each participant was presented with a total of 432 trials, consisting of nine blocks of 48 trials, with equal numbers of 'X' and 'O' stimuli in each block. In the first practice block, the participant was required to respond to the 'X' and 'O' as quickly and accurately as possible by pressing the appropriate response key on the keyboard. The 'z' key corresponded to an 'X' stimulus and the '/' key corresponded to an 'O' stimulus. They were informed that a tone would be heard which they should ignore. On subsequent blocks participants were told to continue responding to the target stimuli as quickly and accurately as possible. Participants were further instructed to listen for the audio tone, which would be randomly and infrequently presented. They were told that the audio tone was now a signal for them to try and stop their responses on that particular trial. They were informed that the computer varies the timing of the beep and some beeps would occur so early that they would always be able to stop, and some so late that would never be able to stop. They were also instructed not to slow down their responses to the primary task stimuli.

The Stop-signal program recorded scores automatically in data files on the computer hard drive. Scores for each participant were taken from his or hers BIS-11 inventory and the Stop-signal data file and matched using the 5-digit participant code. Scores were then transposed into an SPSS (Apache Software, 2005) data file for subsequent analyses. The BIS-11 responses were used to calculate an overall impulsivity score. Some questions were reversed coded and therefore the scores for these questions firstly required recoding. The top and bottom 24.67% (n = 18 for each group) of BIS-11 scores determined the high and low impulsivity groups. Participants who scored in the mid 50% of BIS-11 scores were not allocated to a group and their scores were not employed as between-subjects factor. Scores were also calculated for the first and second order factors relating to BIS-11 motor control. These scores were subsequently used to determine high and low groups based on participant measures of motor inhibition (n = 27) and motor impulsivity (n = 21), respectively.

Results

Statistical Analysis

The stop-signal program generated data files (see Appendix C) containing the following variables: percentage of inhibition (POI), the mean speed to stop the response (SSRT), the mean speed to respond on the primary 'go' trials (MRT) and the mean within-subject standard deviation of reaction time on 'go' trials (SDRT). The SSRT was estimated from the distribution of the reaction times of the primary go-task and the percentage of successful stops.

One-way analyses of variance (ANOVA) were used to analyse performance and psychometric measures with *Group* (low vs. high) as a between-subjects factor. Correlational analyses were employed to investigate the relationship between SSRT and overall BIS-11 scores and also with the BIS-11 subscales representing motor inhibition and motor impulsivity. Analysis of the inhibition function was included employing *Delay* as an additional within-subjects factor.

Demographic Variables

Table 1 indicates the demographic characteristics of the two participant groups ($n = 18$, for each group). The groups did not differ significantly on the measure of age ($F(1,34) = 2.84$, $p = .10$), however this did represent a small sized effect $r = .28$. Stop-signal performance was not significantly different between genders. Based on these results, the factors of age and gender were not considered further in these analyses.

The original BIS-11 study (Patton et al., 1995) reported impulsivity scores for a non-clinical group of undergraduates ($M = 63.82$, $SD = 10.17$), substance-abuse patients ($M = 69.26$, $SD = 10.28$), general psychiatric patients ($M = 71.37$, $SD = 12.61$) and prison inmates ($M = 76.30$, $SD = 11.86$). In the present study the overall

BIS-11 scores employed to differentiate the high-impulsive (*M* = 73.72, *SD* = 5.84) and low-impulsive (*M* = 50.72, *SD* = 4.97) groups were compared to those reported by Patton et al. (1995). The scores obtained in the present study for the *low* group are about 13 points lower than the scores of the non-clinical group reported in the Patton et al. study. The high-impulsive group scores in the current study are approximately 4 points higher than the substance-abuse patients group, and fall within the range of scores reported for the general psychiatric patients and prison inmate groups. These populations are all suggested to be highly impulsive (Cherek et al., 1997; Dawe & Loxton, 2004; Hayaki et al., 2006; Nigg et al., 2006). Therefore the spread of scores employed in the present study may accurately represent high- and low-impulsive groups.

Table 1

Demographic Characteristics of the Sample

Measure	Low-Impulsives (*n* = 18)		High-Impulsives (*n* = 18)		
	Mean	(*SD*)	Mean	(*SD*)	*F*
Age	33.44	(9.50)	27.56	(11.39)	2.84
BIS-11	50.72	(4.97)	73.72	(5.84)	162.00*
MI_1	12.11	(1.75)	18.00	(2.12)	83.05*
MI_2	18.22	(2.26)	26.17	(2.99)	80.60*

Note: Age = in years, BIS-11 = overall impulsivity score, MI_1 = BIS-11 1st order factor motor inhibition subscale, MI_2 = BIS-11 2nd order factor motor impulsiveness subscale.

df = 1, 34; * $p < .05$

Primary 'Go' Task

Table 2 shows the mean reaction times (MRT), standard deviations and accuracy scores for the primary 'go' task for both groups. Across both groups, participants on average performed the primary task at better than 96% accuracy in terms of identifying the stimulus letter and responding with a correct button push. The difference between groups was not significant $F(1,34) = 0.81$, $p = .37$ and the effect was small $r = .15$. Omission errors were also very infrequent for both groups, as shown in the low rates of non-responses to the primary task. The difference in the percentage of omission errors between groups was not significant $F(1,34) = 1.20$, $p = .28$, however this did represent a small effect size $r = .18$.

Mean reaction times on the 'go' task were compared for each group. Levene's test for homogeneity of variances was significant. Therefore the influence of outliers was examined. Outliers were not transformed as variability of responding to the 'go' task may be indicative of disinhibition control (Bellgrove et al., 2004). Consequently the degrees of freedom were adjusted. The mean reaction times to the 'go' task for low-impulsives were slower and more variable ($M = 604.80$ ms, $SD = 177.30$) than high-impulsives ($M = 547.90$ ms, $SD = 115.80$). These differences were not significant $t(29.27) = 1.14$, $p = .26$, and represents a very weak effect size $r = .19$.

Table 2

Mean Reaction Times in Milliseconds (SD), Standard Deviations and Performance Accuracy (in %) to the Primary 'go' *Task*

Measure	Low-Impulsives (n = 18)		High-Impulsives (n = 18)		
	Mean	(*SD*)	Mean	(*SD*)	*F*
'Go' MRT	604.83	(177.30)	547.94	(115.80)	1.30
'Go' SDRT	135.00	(46.10)	122.26	(25.90)	1.05
No response 'go'	0.47	(0.67)	1.21	(2.76)	1.20
Correct response	93.96	(22.81)	98.80	(0.96)	0.81

Note: 'Go' MRT = primary task mean reaction time to 'Go' stimuli on no-signal trials; 'Go' SDRT = standard deviation of response reaction times to 'go' stimuli

df = 1, 34; * $p < .05$

Stop-Signal Reaction Times

The latency of the internal inhibitory response to the stop signal was approximated using the method described by Logan (1994). Average SSRT values for each group across all levels of delays are presented in Table 3. Levene's test for homogeneity of variance between the two groups was non-significant. The results show that the average stop-signal reaction time did not differ significantly between groups $F(1,34) = 0.06$, $p = .82$ and the effect was non-significant $r = .04$.

Table 3

Estimated Stop Signal RT (Mean, SD), Probability of Inhibition (POI)

Measure	Low-Impulsives ($n = 18$)		High-Impulsives ($n = 18$)		
	Mean	(*SD*)	Mean	(*SD*)	*F*
SSRT (mean, (*SD*))	151.28	(116.51)	143.39	(81.40)	0.06
POI (range)	9.58 – 89.81		11.13 – 89.80		
POI (%)	57.30	(12.85)	60.54	(6.79)	0.89

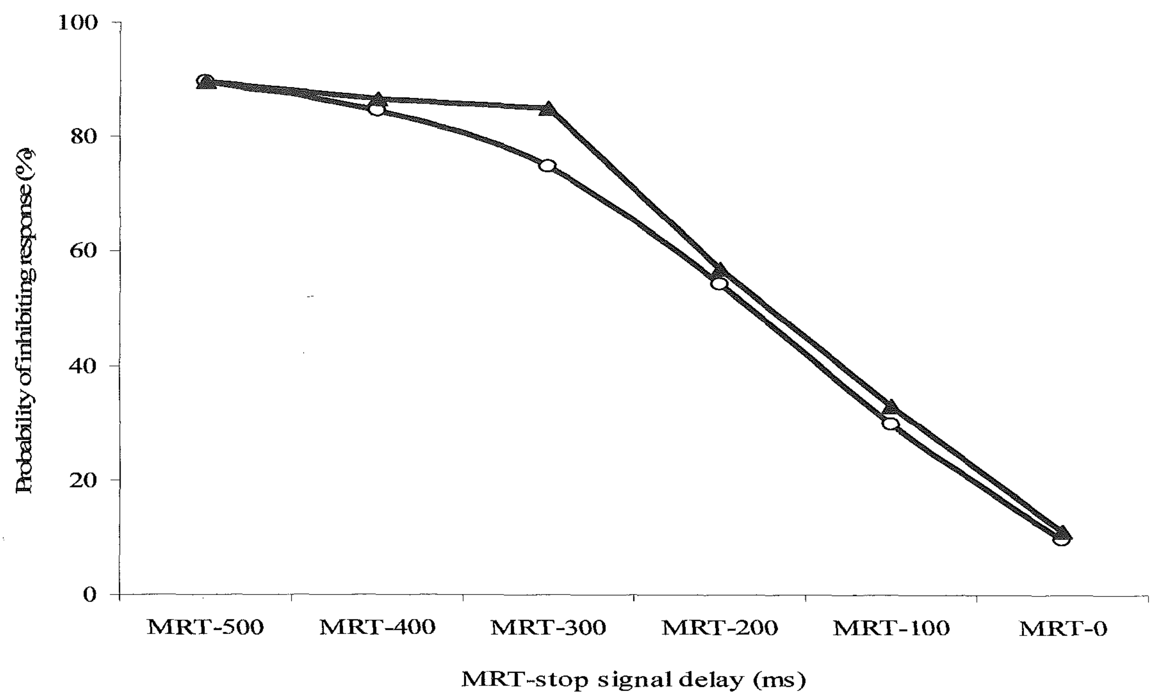
Note: SSRT = stop-signal reaction time, POI (%)= mean inhibition probability across the six stop-signal delays.

*df = 1, 34; * p < .05*

Inhibition Functions

The probability of inhibition (POI) was calculated as the proportion of stop-signal trials at a given delay that were successfully inhibited. As shown in Figure 1 the inhibition functions for each group were plotted by stop-signal delay. Examination of Figure 1 indicated that for each group the probability of inhibiting a response ranged from approximately 10 to 90 percent (see also Table 3). The POI decreased as the stop-signal delay approached MRT.

Figure 1. Probability of inhibiting 'go' responses as a function of stop-signal delay (MRT – stop signal delay) in low- (O) and high-impulsives (▲).



An average of POI across all delays was calculated. Levene's test for equality of variance was significant and the assumption of homogeneity of variance was violated. It was therefore necessary to adjust the degrees of freedom. The POI for low-impulsives were lower and more varied (M = 57.30, SD = 12.85) than those of high-impulsives (M = 60.50, SD = 6.79). However, this difference was not significant $t(25.82) = -.95$, $p = .35$ and signifies a small effect size $r = .18$.

In view of the recommendations of Logan and Cowan (1984) and Logan (1994), these findings suggest that participants did not return deficits in their capacity to inhibit responses. However, because SSRT returns represent an index score averaged across the six levels of stop-signal delay, an additional level of analysis examining the number of non-responses (NNR) at each level of stop-signal delay was undertaken. A one-way ANOVA was conducted on the frequency of non-responding at each level of stop-signal delay (0 ms, 100 ms, 200 ms, 300 ms, 400 ms and 500 ms). The analysis of Stop-signal non-responses at all levels of delay revealed no significant differences between the groups. These findings suggest that response inhibition is not deficient in either group (Badcock et al., 2002).

Correlation Analysis of Stop-Signal Reaction Time and Motor Subscales

Partial one-tailed correlations with the psychometric and performance measures were conducted (see Table 4). When controlling for low- and high-impulsives (n =18, in each group), the results showed a non-significant weak relationship between SSRT and overall BIS-11 score $r = .09, p = .30$, and 1st order factor motor inhibition subscale $r = .12, p = .24$, and 2nd order factor motor impulsiveness subscale $r = .12, p = .25$ respectively. When controlling for low (n = 13) and high (n = 14) motor inhibition scores obtained from the 1st order factor subscale of the BIS-11 a non-significant but medium-strength relationship between SSRT and the motor inhibition subscale score was returned $r = .09, p = .34$. When controlling for low (n = 9) and high (n = 12) motor impulsivity scores derived from the 2nd order factor subscale of the BIS-11, a non-significant weak relationship between SSRT and the motor impulsiveness subscale score was discovered $r = .35, p = .06$.

Table 4

Partial Correlation Coefficients Between High and Low Groups on SSRT

BIS	.09	.24	.17
M_1	.12	.09	.13
M_2	.12	.15	.35
Control Variable	BIS	M_1	M_2
	$n = 36$	$n = 27$	$n = 21$

Note: SSRT = stop-signal reaction time, BIS = Barratt Impulsiveness Scale (11th revision) total score; MI_1 = BIS-11 1st order factor content motor inhibition subscale, MI_2 = BIS-11 2nd order factor motor impulsiveness subscale, Control variable = high and low groupings on that variable.

Recent evidence suggests that variability in responding may indicate inhibitory dysfunction (Bellgrove et al., 2004; Enticott et al., 2006). Therefore, a correlational analysis was performed on overall BIS-11 scores and SDRT, which is the mean within-subject standard deviation of reaction time on 'go' trials. There analysis returned a non-significant weak negative correlation between SDRT and BIS-11 scores when controlling for low- and high-motor impulsives, $r = -0.35$, $p = .06$.

Badcock (2002) suggest that differences in reactions times to the 'go' and 'stop' stimuli may indicate deficits in speed processing and a rebuttal of the argument that a single global mechanism mediates speed processing. A comparison of Go MRT and SSRT from all participants ($n = 73$), found that Go MRT was significantly longer and more varied ($M = 598.80$ ms, $SD = 202.66$) than SSRT ($M = 130.82$ ms, $SD = 114.64$) and that this interaction effect was significant $F(1,72) = 14.48$, $p < .05$). Subsequent analysis with *groups* as a between-subjects factor did not reveal any additional significant differences.

Correlation of Stop-Signal Results from the Current Study with Similar Studies

One final analysis was undertaken to examine the comparability of returns on the Stop-signal Task in this study with two other studies employing similar measures of response inhibition (Lijffijt et al., 2004; Rodriguez-Fornells et al., 2002). The Lijffijt et al. (2004) and Rodriguez-Fornells et al. (2002) studies reported mean Stop-signal reaction times and these are reported in Table 5. These data suggest there are similarities in SSRT across the three studies. However, in the current study there is greater variability seen in the participant SSRT measures. The similarity of the results across the three studies provides some validity to the findings returned in the present study.

Table 5

Comparison of Current Study SSRT and the Lijffijt et al. (2004) and Rodriguez-Fornells et al. (2002) Studies

	Low-Impulsives	High-Impulsives
	Mean (*SD*)	Mean (*SD*)
Current Study	151.28 (116.51)	143.39 (81.40)
Lijffijt et al. (2004)	162.21 (42.93)	165.22 (35.79)
Rodriguez-Fornells et al. (2002)	189.00 (34.00)	188.00 (30.00)

Note: MRT = primary task mean reaction time to Go stimuli on no-signal trials; SSRT = mean stop-signal reaction time.

Discussion

Overview of Results

The primary aim of the present study was to address the question of whether trait Impulsiveness reflects a response inhibition deficit in non-pathological adults. Low and high impulsivity groups, selected using Barratt's Impulsiveness Scale (Patton et al., 1995), were compared on stop-signal performance. The results did not reveal a significant difference between the high and low impulsive groups in stop-signal responding, and therefore the hypotheses of the study are not supported.

Despite participants in the high-impulsive group rating themselves as more impulsive, they did not significantly differ from the low-impulsive group in their speed of inhibiting a response (SSRT) or the probability of response inhibition (POI). SSRT and POI both are believed to be valid measures of response inhibition (Logan, 1994). The results in the current study contradict the findings of studies that have reported a relationship between performance indices of inhibition and the Impulsiveness trait (Avila & Parcet, 2001; Logan et al., 1997; Marsh et al., 2002), but replicates the findings of studies that have not reported a relationship between the two (Cheung et al., 2004; Dimoska & Johnstone, 2007; Fallgatter & Herrmann, 2001; Harmon-Jones et al., 1997; Lijffijt et al., 2004; Rodriguez-Fornells et al., 2002). Correlational analysis of performance and psychometric measures did not support an association between Impulsiveness and SSRT. However, a weak (non-significant) correlation was observed between SSRT and the BIS-11 motor impulsiveness subscale. Whilst correlational analyses prohibit any causal conclusions, the results suggest that these concepts appear somewhat related.

The failure to find any difference in stop-signal measures between low-impulsive and high-impulsive groups is possibly because trait impulsivity measures in non-clinical populations are not sufficiently extreme to reveal significant differences in inhibitory motor control (Lijffijt et al., 2004; Rodriguez-Fornells et al., 2002). Although the results from the current study are inconsistent with the results reported by previous studies (Logan et al., 1997; Visser, Das-Smaal, & Kwakman, 1996), these studies employed clinical populations and were only able to show that impaired stopping was present in those individuals with particularly high levels of impulsivity (Newman et al., 1997; Summerfeldt et al., 2004). Therefore, the relationship between stopping ability and impulsivity might be nonlinear and it is only individuals who possess extremely high levels of self-reported impulsivity that reveal an impairment in stopping ability (Enticott et al., 2006). However, the results returned by the current study replicate other recent studies that have separated non-clinical participants into low-impulsive and high-impulsive groups and have not reported significant differences between groups on SSRT (Lijffijt et al.; Rodriguez-Fornells et al., 2002).

An increase in the time taken to resolve interference as measured by SSRT, was weakly and positively correlated (but not significantly) with motor impulsiveness $r = .35$. This relationship is stronger and positive whereas the correlational relationship reported by Enticott et al. (2006) was weaker and negative $r = -.17$. This may merely reflect an increase in the statistical power of the current study, due to the larger sample size employed ($n = 36$) when compared with the Enticott et al. study ($n = 31$), however the change in direction of the correlation remains indeterminable. This relationship provides limited support for the notion that SSRT may serve as an objective measure of motor impulsivity.

It is possible that stopping ability may be related to impulsivity, but that it is largely dissimilar to the forms of impulsiveness scored by the BIS-11. To understand this relationship, it is necessary to examine the BIS-11 subscales. While the moderate relationship found between motor impulsiveness and SSRT was not unexpected, in view of past findings (Enticott et al., 2006; Swann, Bjork, Moeller, & Dougherty, 2002), the non-significance of the relationship is somewhat surprising, because this scale contains items typically associated with the 'traditional' notions of impulsivity; for example, "I act on impulse", and "I act on the spur of the moment" (Patton et al., 1995). Therefore, this non-significance may reflect a lack of consistency among normal adults to identify inhibition and impulsivity, or an inability of participants to accurately introspect their own impulsiveness, or other demand characteristics. More probably, it reflects the lack of distinctiveness in these items, and the difficulty in consistently rating such imprecise statements (Enticott et al.).

Given that latency of the stopping process is believed to be more variable in high-impulsives which suggests poor inhibitory control (Bellgrove et al., 2004), it was unexpected that the results from the current study would not support an association between overall impulsivity and measures of variable responding (SDRT) $r = .09$. However, when controlling for low- and high-motor impulsivity, there was a weak non-significant negative correlation found between overall impulsivity and SDRT $r = -.35$. This could suggest that the concepts of motor impulsiveness and variability of responding are somewhat related and imply an impairment of motor inhibitory control in low-impulsives (Enticott et al., 2006)

A number of limitations to the current study should be noted. The non-significant SSRT results may indicate that the sample size employed ($n = 36$), did actually lack statistical power and that a larger sample size has the potential to show greater variability in SSRT. There was also difficulties with recruiting sufficient numbers of participants to ensure that all individuals performed the stop-signal task under identical experimental conditions. Subsequently, participants either performed the stop-signal task in a group session held in a university computer laboratory or singularly in a quiet office. This meant that experimental conditions were potentially dissimilar and the results of the study, particularly on measurements of SSRT and POI, were adversely affected.

A number of participants reported that they had experienced difficulty in differentiating between the audio stop-signal of their computer and stop-signals originating from other computers in the laboratory. It has been suggested (Badcock et al., 2002) that as the response latencies of auditory neurons usually lengthen with decreases in stimulus intensity, if the stop-signal was effectively at a lower stimulus intensity for a participant, then this may have resulted in an impairment of inhibitory response. Due to the anonymity afforded to the participants, it was not possible to later identify under which of the two conditions a participant had performed the stop-signal task and therefore an analysis of participant SSRT and POI contrasting the conditions of group or solo testing, was unfortunately not possible. Future research could ensure that participants are presented with an audio 'stop' signal through audio headphones to control for audio interference on participant stop-signal performance.

However, the overall pattern of stop-signal reaction times obtained in this study were consistent with those of previous studies that have also employed adult participants and utilised similar methodology (Logan & Cowan, 1984; Logan et al., 1984). The average SSRTs of the high-impulsive and low-impulsive groups were both close to 200 ms, which is the RT measures typically reported by stop-signal studies (Logan et al.). Additionally, as expected these values tended to decrease (for both groups) as the stop-signal delay increased (Badcock et al., 2002).

There was also an observed dissociation between latency effects on response execution versus response inhibition, similar to those reported by Badcock et al. (2002). This was indicated by the significantly slower 'go' responses versus normal stop-signal reaction times. This finding invalidates the argument that a single global mechanism mediates speeded processing (Badcock et al., 2002) and adds further support to studies that confirm the independence of the processes involved in response execution and inhibition (De Jong, Coles, Logan, & Gratton, 1990; Tannock, Schachar, & Logan, 1995).

There was no significant difference noted in the probability of response inhibition between either the low-impulsive or high-impulsive group. This is unexpected as previous research has shown that the deficits that occur in highly impulsive participants are due to deficient inhibitory control (Badcock et al., 2002). Relative to the high-impulsive group the slope of the inhibition functions of the low-impulsive group was flatter, and this is said to indicate poorer inhibitory control (Logan, 1994). However, it must be noted that the difference in mean probability of inhibition for either group was not significant. Also, the difference in the variability in stop latencies between the groups was not significant and this does not appear to be the reason for the difference in the slopes of the inhibition functions. However, according to Badcock et al. (2002) this may indicate that in the low-impulsive group the inhibitory response was triggered less often. Therefore, the flatter inhibition functions generated by the low-impulsive group may be attributed to either a generalised impairment or possibly inattention to the task.

Motivation and inattention may influence the probability of the inhibitory response being triggered (Castellanos & Tannock, 2002). Also, a slowing of SSRT may result from a deficiency of attending to stimuli (Lijffijt et al., 2004). However, poor motivational state does not provide an adequate account of the current data. The consistently high accuracy rates of approximately 96% for all participants to the task of identifying the target stimuli is testimony to the effort participants invested in the task demands. Therefore, it appears improbable that the results could have occurred due to any differences between the groups in either their enthusiasm or attention to the task and these do not explain the differences in success of inhibition. The source of the difference in the slope of the inhibition functions between the high and low groups is assumed to originate elsewhere, due to some other extraneous factor.

One further account for the lack of significant supportive evidence regarding the relationship between impulsivity and inhibition is that the results were obtained under testing conditions that were conducted in a relatively neutral environment. It has been suggested (Mezzacappa, Kindlon, Saul, & Earls, 1998; Quilty & Oakman, 2004; Schulz et al., 2007) that under conditions of stress, highly impulsive individuals may be more predisposed to poor inhibitory control. The apparent lack of stress experienced by the participants in the current experiment may partially explain the non-significance of many of the observed correlations. Future investigations may wish to evaluate the relationship between inhibition and impulsivity under conditions of cognitive or emotional load.

Conclusion

The analysis of performance of a high impulsivity BIS-11 score versus a low impulsivity BIS-11 score group, on a stop-signal task revealed no significant differences between the groups. These findings suggest that despite differentiating participants into high versus low impulsivity groups on the basis of the BIS-11 score, no differences in the capacity to inhibit behaviour was observed. Whether the non-significant results are an artefact of a deficiency of impulsivity measurement, or experimental design, is indeterminable. However, collectively the findings do not suggest that a high measure of trait impulsivity in non-clinical adults is due to a deficiency in motor or response inhibition processes. Future research is required to identify the underlying mechanisms involved in the inhibition of action for low and high-impulsive groups. This may be achieved by comparing clinical and non-clinical forms of impulsivity, that are believed to include both behavioural and cognitive characteristics of impulsivity.

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Appendix A

Participant Information Form

EDITH COWAN UNIVERSITY

Faculty of Computing, Health and Science
School of Psychology
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027

August 2007

Student Project Title: Motoric Inhibition: Impulsivity and the Ability to Inhibit Action

Dear Sir/Madam

My name is Lindsay Vibert, I am conducting a research project that is part of the requirements for my Honours in Psychology degree. The project has been approved by the Faculty of Computing, Health and Science Ethics Committee, and will be supervised by two members of the ECU School of Psychology, Drs. Chris Theunissen and Greg Dear. This research project involves understanding the ways in which cognitions and personality interact.

Participants will be adults aged over 18 years. If you agree to participate, you will be asked to complete two questionnaires and to perform a computer based task in an ECU computer laboratory. It is expected that in most cases the study will last approximately 45 minutes. The results will be recorded to allow accurate classification of your responses to the questionnaire and to analyse the data output from the computer-based activity.

It is important to note that there are no 'right' or 'wrong' answers to the questions you will be asked. All information gathered as part of this project will be treated as strictly confidential and you will be provided with a randomly allocated unique 5-digit participant identification number. You will be required to write this number on both questionnaires and also to input the number into the computer program task, when prompted to do so. The identification number will allow me to relate all documents back to each participant but will not be linked to your name. Consequently, neither your name nor any other details that could distinguish you will be used in any report based on this research.

Participation in this research project is on a voluntary basis and if you wish to, you may withdraw at any time. Should you withdraw all materials collected from you will be destroyed.

If you have any queries about this project or would like further information please contact the Principal Research Supervisor, Chris Theunissen (6304 5834) c.theunissen@ecu.edu.au or the researcher, Lindsay Vibert lvibert@student.ecu.edu.au.

If you have any other concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Dr. Dianne McKillop
Fourth Year Coordinator
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: (6304 5736)
Email: d.mckillop@ecu.edu.au

Yours sincerely

Lindsay Vibert
(Researcher)

Appendix B

Participant Informed Consent Form

Motoric Inhibition: Impulsivity and the Ability to Inhibit Action

I, ________________________________ (the participant) have read the information letter provided with this consent form and understand the requirements. Also, any questions I have asked have been answered to my satisfaction.

I agree to participate in the completion of the two questionnaires and the computer based activity associated with this research. I understand that I may withdraw my consent at any time.

I agree that the research gathered during this project can be used to complete a student report, provided I am not identified in any way.

Signed

____

September 2007

Appendix C

Barratt Impulsiveness Scale Version 11

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and **put an X on the appropriate circle** on the right side of this page. Don't spend too much time on any statement. Answer quickly and honestly.

ID Code: ____________

		Rarely/Never	**Occasionally**	**Often**	**Almost Always**
1.	I plan tasks carefully.	O	O	O	O
2.	I do things without thinking.	O	O	O	O
3.	I make-up my mind quickly.	O	O	O	O
4.	I am happy-go-lucky.	O	O	O	O
5.	I don't "pay attention."	O	O	O	O
6.	I have "racing" thoughts.	O	O	O	O
7.	I plan trips well ahead of time.	O	O	O	O
8.	I am self controlled.	O	O	O	O
9.	I concentrate easily.	O	O	O	O
10.	I save regularly.	O	O	O	O
11.	I "squirm" at plays or lectures.	O	O	O	O
12.	I am a careful thinker.	O	O	O	O
13.	I plan for job security.	O	O	O	O
14.	I say things without thinking.	O	O	O	O
15.	I like to think about complex problems.	O	O	O	O
16.	I change jobs.	O	O	O	O
17.	I act "on impulse."	O	O	O	O
18.	I get easily bored when solving thought problems.	O	O	O	O
19.	I act on the spur of the moment.	O	O	O	O
20.	I am a steady thinker.	O	O	O	O
21.	I change residences.	O	O	O	O
22.	I buy things on impulse.	O	O	O	O
23.	I can only think about one thing at a time.	O	O	O	O
24.	I change hobbies.	O	O	O	O
25.	I spend or charge more than I earn.	O	O	O	O
26.	I often have extraneous thoughts when thinking.	O	O	O	O
27.	I am more interested in the present than the future.	O	O	O	O
28.	I am restless at the theater or lectures.	O	O	O	O
29.	I like puzzles.	O	O	O	O
30.	I am future oriented.	O	O	O	O

Appendix D

Instructions for the Stop-signal Task

Stop-Signal Task Practice Block Instructions

"In this task you'll be shown a series of characters presented one at a time in the centre of the screen. Your task is to indicate whether each character is an 'O' or an 'X' by pressing the corresponding key on the keyboard. Sometimes the computer will beep while the character is presented. This will be important later, but for the moment just ignore it. Rest a finger of one hand on one of the response keys and a finger of the other hand on the other response key. Respond as quickly and as accurately as possible."

Stop-Signal Task Main Blocks Instructions

"That was the end of practice on this task. The following trials will be the same, only now we want you to listen as well for the beeps that the computer makes when a character is presented. Respond as quickly and as accurately as possible, but DO NOT respond when the beep occurs. The computer varies the timing of the beep. Some beeps will occur so early that you will always be able to stop, and some so late that you will never be able to stop. Stop if you can, but don't worry if you can't. Don't let the beeps interfere with your performance on the task. Don't delay your responses in order to improve your chances of stopping."

Appendix E

Example of Participant Data File Created by the Stop-signal Program

#FORMAT:[MARKER] [GROUP] [BLOCK] [TRIAL] [STIM] [RESP_FLAG(0=NONE)] [RT(0=NONE)] [RW(-1=NO_RESP)] [SS_FLAG(1=SS)] [SS_DELAY_REL_MNRT_MS]

```
□ 1 1  1 X 1  728  0  0   1
□ 1 1  2 X 1  571  0  0   1
□ 1 1  3 O 1  712  0  1   0
□ 1 1  4 X 1  622  0  0   1
□ 1 1  5 X 1  660  0  0   1
□ 1 1  6 X 1  501  0  0   1
□ 1 1  7 X 1  453  0  1 -300
□ 1 1  8 O 1  463  0  0   1
□ 1 1  9 O 1  522  0  1 -400
□ 1 1 10 X 1  489  0  0   1
□ 1 1 11 X 1  544  0  0   1
□ 1 1 12 O 1  508  0  0   1
□ 1 1 13 X 1  550  0  0   1
□ 1 1 14 O 1  525  0  0   1
□ 1 1 15 X 1  539  0  1 -100
□ 1 1 16 O 1  542  0  0   1
□ 1 1 17 O 1  501  0  0   1
□ 1 1 18 X 0    0 -1  1 -500
□ 1 1 19 X 1  511  0  0   1
□ 1 1 20 O 1  481  0  0   1
□ 1 1 21 O 1  393  0  0   1
□ 1 1 22 X 1  396  0  0   1
□ 1 1 23 X 1  467  0  0   1
□ 1 1 24 O 1  524  0  0   1
□ 1 1 25 O 1  371  0  0   1
□ 1 1 26 X 1  473  0  0   1
□ 1 1 27 O 1  467  0  0   1
□ 1 1 28 O 1  526  0  0   1
□ 1 1 29 X 1  424  0  0   1
□ 1 1 30 O 1  428  0  0   1
□ 1 1 31 X 0    0 -1  1 -400
□ 1 1 32 O 0    0 -1  1 -300
□ 1 1 33 X 1  452  0  0   1
□ 1 1 34 X 1  438  0  0   1
□ 1 1 35 X 1  536  0  0   1
□ 1 1 36 X 1  377  0  0   1
□ 1 1 37 O 1  429  0  1 -100
□ 1 1 38 O 1  575  0  0   1
□ 1 1 39 O 1  360  0  0   1
□ 1 1 40 O 1  548  0  0   1
□ 1 1 41 O 0    0 -1  1 -500
□ 1 1 42 X 1  517  0  1   0
```

□	1	1	43	X	1	574	0	0	1
□	1	1	44	O	1	569	0	0	1
□	1	1	45	O	1	508	0	1	-200
□	1	1	46	X	1	491	0	1	-200
□	1	1	47	O	1	666	0	0	1
□	1	1	48	O	1	617	0	0	1
□	1	2	1	X	1	710	0	0	1
□	1	2	2	X	1	507	0	0	1
□	1	2	3	X	1	991	0	0	1
□	1	2	4	O	1	718	0	0	1
□	1	2	5	O	1	381	0	0	1
□	1	2	6	X	0	0	-1	1	-300
□	1	2	7	X	1	407	0	0	1
□	1	2	8	X	1	439	0	0	1
□	1	2	9	X	1	323	0	1	0
□	1	2	10	O	1	688	0	0	1
□	1	2	11	X	1	406	0	0	1
□	1	2	12	O	1	462	0	0	1
□	1	2	13	O	1	441	0	0	1
□	1	2	14	X	1	552	0	0	1
□	1	2	15	O	1	371	0	0	1
□	1	2	16	X	0	0	-1	1	-500
□	1	2	17	O	1	507	0	1	-200
□	1	2	18	O	1	405	0	0	1
□	1	2	19	O	1	336	0	1	-300
□	1	2	20	O	0	0	-1	1	-500
□	1	2	21	O	0	0	-1	1	-400
□	1	2	22	X	1	504	0	0	1
□	1	2	23	O	1	397	0	0	1
□	1	2	24	X	1	444	0	0	1
□	1	2	25	X	0	0	-1	1	-400
□	1	2	26	X	1	354	0	0	1
□	1	2	27	X	1	382	0	0	1
□	1	2	28	O	1	427	0	0	1
□	1	2	29	O	1	426	0	0	1
□	1	2	30	O	1	421	0	0	1
□	1	2	31	O	1	311	0	1	0
□	1	2	32	O	1	365	0	0	1
□	1	2	33	X	1	488	0	0	1
□	1	2	34	O	1	301	0	0	1
□	1	2	35	X	1	383	0	1	-100
□	1	2	36	X	1	443	0	0	1
□	1	2	37	O	1	406	0	0	1
□	1	2	38	O	1	300	0	1	-100
□	1	2	39	O	1	367	0	0	1
□	1	2	40	X	1	379	0	0	1
□	1	2	41	X	1	377	0	0	1
□	1	2	42	X	1	343	0	0	1
□	1	2	43	X	1	322	0	1	-200
□	1	2	44	X	1	272	0	0	1

□ 1 2 45 O 1 364 0 0 1
□ 1 2 46 O 1 329 0 0 1
□ 1 2 47 O 1 339 0 0 1
□ 1 2 48 X 1 362 0 0 1
□ 1 3 1 O 1 568 0 0 1
□ 1 3 2 O 1 330 0 1 -200
□ 1 3 3 O 1 455 0 0 1
□ 1 3 4 O 1 315 0 0 1
□ 1 3 5 O 0 0 -1 1 -300
□ 1 3 6 X 1 414 0 0 1
□ 1 3 7 X 1 402 0 0 1
□ 1 3 8 X 1 314 0 0 1
□ 1 3 9 O 1 407 0 0 1
□ 1 3 10 X 1 511 0 0 1
□ 1 3 11 O 1 399 0 1 0
□ 1 3 12 O 1 446 0 0 1
□ 1 3 13 O 1 436 0 0 1
□ 1 3 14 O 1 317 0 0 1
□ 1 3 15 X 0 0 -1 1 -300
□ 1 3 16 O 1 432 0 0 1
□ 1 3 17 O 1 299 0 0 1
□ 1 3 18 X 0 0 -1 1 -400
□ 1 3 19 X 1 432 0 0 1
□ 1 3 20 X 1 345 0 0 1
□ 1 3 21 X 1 350 0 1 -100
□ 1 3 22 O 1 510 0 0 1
□ 1 3 23 X 1 878 0 0 1
□ 1 3 24 X 1 471 0 0 1
□ 1 3 25 X 1 327 0 1 0
□ 1 3 26 O 1 643 0 0 1
□ 1 3 27 O 1 366 0 0 1
□ 1 3 28 O 1 334 0 0 1
□ 1 3 29 X 1 434 0 0 1
□ 1 3 30 X 1 502 0 0 1
□ 1 3 31 X 1 523 0 0 1
□ 1 3 32 X 1 374 0 0 1
□ 1 3 33 X 1 318 0 0 1
□ 1 3 34 O 1 400 0 0 1
□ 1 3 35 O 1 425 0 0 1
□ 1 3 36 X 0 0 -1 1 -200
□ 1 3 37 O 0 0 -1 1 -500
□ 1 3 38 O 1 380 0 1 -100
□ 1 3 39 O 1 409 0 0 1
□ 1 3 40 X 1 445 0 0 1
□ 1 3 41 O 0 0 -1 1 -400
□ 1 3 42 X 1 382 0 0 1
□ 1 3 43 X 1 358 0 0 1
□ 1 3 44 O 1 502 0 0 1
□ 1 3 45 O 1 356 0 0 1
□ 1 3 46 X 0 0 -1 1 -500

□	1	3	47	X	1	373	0	0	1
□	1	3	48	X	1	389	0	0	1
□	2	1	1	O	1	644	0	0	1
□	2	1	2	X	1	610	0	0	1
□	2	1	3	X	1	381	0	0	1
□	2	1	4	O	1	433	0	0	1
□	2	1	5	O	1	338	0	0	1
□	2	1	6	X	1	555	0	0	1
□	2	1	7	X	0	0	-1	1	-500
□	2	1	8	O	0	0	-1	1	-300
□	2	1	9	O	1	348	0	0	1
□	2	1	10	O	1	302	0	0	1
□	2	1	11	O	1	345	0	0	1
□	2	1	12	X	1	618	0	0	1
□	2	1	13	X	1	436	0	0	1
□	2	1	14	X	1	450	0	0	1
□	2	1	15	O	1	418	0	0	1
□	2	1	16	O	1	448	0	0	1
□	2	1	17	X	1	385	0	0	1
□	2	1	18	X	1	313	0	0	1
□	2	1	19	X	1	352	0	0	1
□	2	1	20	X	0	0	-1	1	-400
□	2	1	21	X	0	0	-1	1	-300
□	2	1	22	O	1	415	0	0	1
□	2	1	23	O	1	294	0	0	1
□	2	1	24	O	1	308	0	0	1
□	2	1	25	X	1	381	0	0	1
□	2	1	26	O	1	450	0	0	1
□	2	1	27	X	1	408	0	0	1
□	2	1	28	O	1	380	0	0	1
□	2	1	29	O	1	402	0	0	1
□	2	1	30	O	1	313	0	0	1
□	2	1	31	X	1	427	0	0	1
□	2	1	32	X	1	640	0	0	1
□	2	1	33	X	1	303	0	0	1
□	2	1	34	O	1	414	0	1	-100
□	2	1	35	O	1	349	0	0	1
□	2	1	36	O	0	0	-1	1	-500
□	2	1	37	X	1	362	0	1	-100
□	2	1	38	X	0	0	-1	1	-200
□	2	1	39	O	1	322	0	1	0
□	2	1	40	O	1	271	0	1	-200
□	2	1	41	O	0	0	-1	1	-400
□	2	1	42	X	1	467	0	0	1
□	2	1	43	O	1	341	0	0	1
□	2	1	44	O	1	357	0	0	1
□	2	1	45	X	1	390	0	0	1
□	2	1	46	X	1	333	0	0	1
□	2	1	47	X	1	448	0	0	1
□	2	1	48	X	1	327	0	1	0

□	2	2	1	O	1	461	0	0	1
□	2	2	2	O	1	273	0	0	1
□	2	2	3	X	1	223	1	1	0
□	2	2	4	O	1	595	0	1	-300
□	2	2	5	X	1	556	0	0	1
□	2	2	6	O	1	333	0	0	1
□	2	2	7	O	1	327	0	0	1
□	2	2	8	X	0	0	-1	1	-400
□	2	2	9	O	1	278	0	0	1
□	2	2	10	X	1	423	0	0	1
□	2	2	11	O	1	512	0	0	1
□	2	2	12	O	1	304	0	0	1
□	2	2	13	O	1	333	0	0	1
□	2	2	14	X	0	0	-1	1	-500
□	2	2	15	O	1	405	0	0	1
□	2	2	16	O	1	321	0	0	1
□	2	2	17	O	1	322	0	0	1
□	2	2	18	X	1	407	0	0	1
□	2	2	19	O	1	411	0	1	0
□	2	2	20	O	1	365	0	0	1
□	2	2	21	O	0	0	-1	1	-500
□	2	2	22	O	1	570	0	0	1
□	2	2	23	X	1	537	0	0	1
□	2	2	24	O	1	520	0	0	1
□	2	2	25	X	1	370	0	0	1
□	2	2	26	O	1	314	0	1	-200
□	2	2	27	X	1	522	0	0	1
□	2	2	28	X	1	448	0	0	1
□	2	2	29	X	1	330	0	0	1
□	2	2	30	X	1	330	0	0	1
□	2	2	31	X	1	249	0	0	1
□	2	2	32	O	1	356	0	0	1
□	2	2	33	X	1	448	0	0	1
□	2	2	34	O	0	0	-1	1	-400
□	2	2	35	X	1	393	0	0	1
□	2	2	36	X	1	340	0	0	1
□	2	2	37	O	1	378	0	0	1
□	2	2	38	X	1	337	0	1	-200
□	2	2	39	X	1	453	0	0	1
□	2	2	40	O	1	358	0	1	-100
□	2	2	41	X	1	330	0	0	1
□	2	2	42	X	1	448	0	0	1
□	2	2	43	X	0	0	-1	1	-300
□	2	2	44	X	1	329	0	1	-100
□	2	2	45	O	1	403	0	0	1
□	2	2	46	O	1	372	0	0	1
□	2	2	47	X	1	385	0	0	1
□	2	2	48	X	1	365	0	0	1
□	2	3	1	O	0	0	-1	1	-400
□	2	3	2	X	1	482	0	0	1

□ 2 3 3 O 1 482 0 0 1
□ 2 3 4 O 1 304 0 0 1
□ 2 3 5 O 1 290 0 1 0
□ 2 3 6 X 1 391 0 0 1
□ 2 3 7 X 1 383 1 0 1
□ 2 3 8 O 1 435 0 0 1
□ 2 3 9 X 1 482 0 0 1
□ 2 3 10 X 1 347 0 0 1
□ 2 3 11 O 1 400 0 0 1
□ 2 3 12 O 0 0 -1 1 -300
□ 2 3 13 X 1 562 0 0 1
□ 2 3 14 O 1 643 0 0 1
□ 2 3 15 X 0 0 -1 1 -300
□ 2 3 16 X 1 335 0 0 1
□ 2 3 17 O 1 358 0 0 1
□ 2 3 18 O 1 377 0 1 -200
□ 2 3 19 O 1 542 0 0 1
□ 2 3 20 X 1 386 0 0 1
□ 2 3 21 X 1 386 0 0 1
□ 2 3 22 O 1 324 0 0 1
□ 2 3 23 X 1 346 0 0 1
□ 2 3 24 X 1 312 0 1 0
□ 2 3 25 O 1 310 0 0 1
□ 2 3 26 X 1 403 0 0 1
□ 2 3 27 X 0 0 -1 1 -500
□ 2 3 28 O 1 385 0 0 1
□ 2 3 29 X 1 411 0 0 1
□ 2 3 30 X 1 398 0 1 -200
□ 2 3 31 X 1 318 0 1 -100
□ 2 3 32 O 1 446 0 0 1
□ 2 3 33 O 1 383 0 0 1
□ 2 3 34 O 1 352 1 0 1
□ 2 3 35 X 1 497 0 0 1
□ 2 3 36 X 1 529 0 0 1
□ 2 3 37 O 1 337 0 1 -100
□ 2 3 38 X 1 464 0 0 1
□ 2 3 39 X 0 0 -1 1 -400
□ 2 3 40 O 1 357 0 0 1
□ 2 3 41 O 1 455 0 0 1
□ 2 3 42 O 1 362 0 0 1
□ 2 3 43 X 1 446 0 0 1
□ 2 3 44 O 0 0 -1 1 -500
□ 2 3 45 O 1 439 0 0 1
□ 2 3 46 X 1 345 0 0 1
□ 2 3 47 X 1 442 0 0 1
□ 2 3 48 O 1 415 0 0 1
□ 3 1 1 X 1 542 0 0 1
□ 3 1 2 O 0 0 -1 1 -200
□ 3 1 3 O 1 350 0 0 1
□ 3 1 4 X 1 420 0 0 1

□ 3 1 5 O 1 358 0 0 1
□ 3 1 6 O 0 0 -1 1 -500
□ 3 1 7 O 1 344 0 0 1
□ 3 1 8 X 1 355 0 1 -100
□ 3 1 9 X 1 449 0 0 1
□ 3 1 10 X 1 324 0 0 1
□ 3 1 11 O 1 369 0 0 1
□ 3 1 12 O 1 315 0 0 1
□ 3 1 13 X 1 525 0 0 1
□ 3 1 14 X 1 289 0 1 0
□ 3 1 15 O 1 363 0 0 1
□ 3 1 16 X 1 342 0 0 1
□ 3 1 17 X 1 335 0 0 1
□ 3 1 18 X 1 304 0 0 1
□ 3 1 19 X 1 317 0 0 1
□ 3 1 20 X 1 280 0 0 1
□ 3 1 21 O 1 372 0 0 1
□ 3 1 22 O 1 405 0 0 1
□ 3 1 23 O 1 267 0 0 1
□ 3 1 24 O 0 0 -1 1 -400
□ 3 1 25 X 1 313 1 0 1
□ 3 1 26 X 1 293 0 1 -200
□ 3 1 27 O 1 372 0 0 1
□ 3 1 28 O 1 405 0 0 1
□ 3 1 29 X 1 391 0 0 1
□ 3 1 30 O 1 429 0 0 1
□ 3 1 31 X 1 301 0 0 1
□ 3 1 32 X 1 261 0 0 1
□ 3 1 33 O 1 432 0 1 0
□ 3 1 34 X 1 401 0 0 1
□ 3 1 35 X 1 341 1 0 1
□ 3 1 36 X 0 0 -1 1 -400
□ 3 1 37 O 1 384 0 0 1
□ 3 1 38 O 1 467 0 1 -100
□ 3 1 39 X 0 0 -1 1 -300
□ 3 1 40 O 1 417 0 0 1
□ 3 1 41 O 1 429 0 0 1
□ 3 1 42 X 1 413 0 0 1
□ 3 1 43 O 1 356 0 0 1
□ 3 1 44 O 1 319 0 0 1
□ 3 1 45 O 1 368 0 0 1
□ 3 1 46 O 0 0 -1 1 -300
□ 3 1 47 X 0 0 -1 1 -500
□ 3 1 48 X 1 367 0 0 1
□ 3 2 1 O 1 679 0 0 1
□ 3 2 2 X 1 367 0 0 1
□ 3 2 3 X 1 321 0 0 1
□ 3 2 4 X 1 312 0 1 0
□ 3 2 5 X 1 308 0 0 1
□ 3 2 6 O 1 337 0 0 1

□ 3 2 7 X 1 599 0 1 -500
□ 3 2 8 O 1 382 0 0 1
□ 3 2 9 X 0 0 -1 1 -300
□ 3 2 10 X 0 0 -1 1 -400
□ 3 2 11 O 1 403 0 0 1
□ 3 2 12 O 1 417 0 0 1
□ 3 2 13 O 1 342 0 1 0
□ 3 2 14 X 1 482 0 0 1
□ 3 2 15 O 1 358 0 0 1
□ 3 2 16 O 1 334 0 0 1
□ 3 2 17 O 0 0 -1 1 -500
□ 3 2 18 X 1 359 0 0 1
□ 3 2 19 X 1 306 0 0 1
□ 3 2 20 O 1 471 0 0 1
□ 3 2 21 O 1 267 0 0 1
□ 3 2 22 X 1 323 0 0 1
□ 3 2 23 X 1 424 0 0 1
□ 3 2 24 O 1 341 0 0 1
□ 3 2 25 X 1 361 0 0 1
□ 3 2 26 X 1 327 1 0 1
□ 3 2 27 X 1 410 0 0 1
□ 3 2 28 O 1 400 0 0 1
□ 3 2 29 X 1 272 0 0 1
□ 3 2 30 X 1 391 0 0 1
□ 3 2 31 O 1 404 1 0 1
□ 3 2 32 O 1 316 0 0 1
□ 3 2 33 O 1 417 0 1 -300
□ 3 2 34 X 1 406 0 1 -100
□ 3 2 35 O 1 403 0 1 -200
□ 3 2 36 X 1 379 0 0 1
□ 3 2 37 O 1 373 0 0 1
□ 3 2 38 O 1 448 0 1 -100
□ 3 2 39 O 1 361 0 0 1
□ 3 2 40 X 1 446 0 0 1
□ 3 2 41 O 0 0 -1 1 -400
□ 3 2 42 O 1 404 0 0 1
□ 3 2 43 X 1 383 0 1 -200
□ 3 2 44 X 1 297 0 0 1
□ 3 2 45 X 1 373 0 0 1
□ 3 2 46 O 1 396 0 0 1
□ 3 2 47 X 1 381 0 0 1
□ 3 2 48 O 1 385 0 0 1
□ 3 3 1 X 0 0 -1 1 -500
□ 3 3 2 X 1 405 0 0 1
□ 3 3 3 O 1 306 0 1 -200
□ 3 3 4 X 1 379 0 0 1
□ 3 3 5 X 1 288 0 0 1
□ 3 3 6 O 1 328 0 0 1
□ 3 3 7 X 1 319 0 0 1
□ 3 3 8 X 1 274 0 0 1

□	3	3	9	O	1	318	0	0	1
□	3	3	10	O	1	311	0	0	1
□	3	3	11	O	1	271	0	0	1
□	3	3	12	X	1	379	0	0	1
□	3	3	13	O	1	396	0	0	1
□	3	3	14	O	1	402	0	0	1
□	3	3	15	X	0	0	-1	1	-400
□	3	3	16	X	1	508	0	0	1
□	3	3	17	X	0	0	-1	1	-300
□	3	3	18	X	1	496	0	0	1
□	3	3	19	X	1	413	0	0	1
□	3	3	20	X	1	373	0	0	1
□	3	3	21	O	0	0	-1	1	-500
□	3	3	22	X	1	484	0	0	1
□	3	3	23	O	1	389	0	0	1
□	3	3	24	O	1	305	0	0	1
□	3	3	25	X	1	359	0	0	1
□	3	3	26	O	1	318	1	0	1
□	3	3	27	X	1	666	0	0	1
□	3	3	28	O	1	423	0	0	1
□	3	3	29	O	1	331	0	0	1
□	3	3	30	X	1	381	0	0	1
□	3	3	31	O	1	351	0	0	1
□	3	3	32	O	1	298	0	0	1
□	3	3	33	X	1	322	0	1	-200
□	3	3	34	O	0	0	-1	1	-300
□	3	3	35	X	1	426	0	0	1
□	3	3	36	O	1	338	0	0	1
□	3	3	37	O	1	465	0	0	1
□	3	3	38	O	1	370	0	0	1
□	3	3	39	O	1	319	0	1	-100
□	3	3	40	O	1	331	0	1	0
□	3	3	41	X	1	358	0	0	1
□	3	3	42	O	1	397	0	0	1
□	3	3	43	O	0	0	-1	1	-400
□	3	3	44	O	1	428	0	0	1
□	3	3	45	X	1	342	0	0	1
□	3	3	46	X	1	313	0	1	-100
□	3	3	47	X	1	412	0	1	0
□	3	3	48	X	1	359	0	0	1

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Data for Subject 10001, (saved to c:\cc\ccssp\data\s0010001.dat)

MRT (Non-SS EXPT): 414 ms (SDRT = 99.60, N = 324)

Percent Errors :

XO ID : 97.9 (373/381)

Non-response: 0.0 (0/324)

Percent Non-response to SS trials by SS-delay (-99 = Not calculable)

0 ms : 0.0 (0/18), SSRT = -414.00 ms, ZRFT = -99.00

100 ms : 0.0 (0/18), SSRT = -314.00 ms, ZRFT = -99.00

200 ms : 16.7 (3/18), SSRT = 287.00 ms, ZRFT = -0.87

300 ms : 77.8 (14/18), SSRT = 227.00 ms, ZRFT = 0.73

400 ms : 94.4 (17/18), SSRT = 287.00 ms, ZRFT = 1.13

500 ms : 94.4 (17/18), SSRT = 387.00 ms, ZRFT = 1.13

Mean Calculable SSRT = 76.67 ms

Appendix F

Stop-signal Data Set

	Non Stop-Signal Data				Delay SS-0 (MRT-0)		Delay SS-100 (MRT-100)			Delay SS-200 (MRT-200)				Delay SS-300 (MRT-300)		Delay SS-400 (MRT-400)			Delay SS-50	
Part #	MRT (ms)	SDRT	XO ID	NR	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR
10001	414	99.60	97.90	0.00	0.00	-414.00	-99.00	0.00	-314.00	-99.00	16.70	287.00	-0.87	77.80	227.00	0.73	94.40	287.00	1.13	94.40
10002	453	96.15	99.70	0.30	5.60	175.00	-1.82	27.80	135.83	-0.37	72.20	140.00	0.62	100.00	-153.00	-99.00	100.00	-53.00	-99.00	100.00
10003	1074	186.92	100.00	0.00	44.90	40.00	-0.21	44.40	140.00	-0.21	77.80	62.00	0.74	100.00	-774.00	-99.00	100.00	-674.00	-99.00	100.00
10004	576	137.98	98.60	1.50	5.60	275.67	-2.00	38.90	110.89	-0.08	44.40	198.00	0.01	77.80	199.89	0.73	88.90	249.00	1.09	88.90
10005	501	95.43	99.20	0.00	0.00	-501.00	-99.00	16.70	186.00	-0.90	33.30	224.00	-0.25	55.60	281.00	0.20	77.80	326.00	0.78	88.90
10006	620	118.17	99.70	0.00	11.10	130.00	-1.10	22.20	171.00	-0.60	55.60	183.00	0.14	83.30	183.00	0.99	100.00	-220.00	-99.00	94.40
10007	705	124.48	100.00	11.70	11.10	154.89	-1.24	44.40	108.89	-0.07	50.00	196.00	0.03	94.40	77.89	1.78	88.90	270.00	1.04	100.00
10008	776	183.53	100.00	1.20	22.20	141.78	-0.77	61.10	37.00	0.34	83.30	7.00	1.05	88.90	75.56	1.22	94.40	136.78	1.43	94.40
10009	554	123.68	99.70	0.00	0.00	-554.00	-99.00	22.20	166.00	-0.53	50.00	183.00	0.14	94.40	149.00	1.22	94.40	249.00	1.22	94.40
10010	558	126.72	99.70	0.30	0.00	-558.00	-99.00	22.20	157.22	-0.45	55.60	168.56	0.25	83.30	194.83	0.83	100.00	-158.00	-99.00	94.40
10011	655	132.37	99.70	0.00	0.00	-655.00	-99.00	22.20	184.00	-0.63	33.30	238.00	-0.29	88.90	159.00	1.07	88.90	259.00	1.07	83.30
10012	762	136.67	99.70	0.30	33.33	60.00	-0.44	44.40	123.00	-0.17	66.70	153.67	0.34	88.90	139.78	1.17	88.90	239.78	1.17	100.00
10013	907	194.01	100.00	0.30	16.70	195.17	-1.01	55.60	52.56	0.24	66.70	111.67	0.46	88.90	67.44	1.20	94.40	52.50	1.79	88.90
10014	514	113.56	100.00	0.30	5.60	152.61	-1.34	0.00	-414.00	-99.00	5.60	352.61	-1.34	50.00	283.50	0.15	77.80	326.33	0.65	94.40
10015	448	86.28	98.70	0.30	5.60	150.06	-1.74	5.60	250.06	-1.74	38.90	213.39	-0.16	77.80	229.00	0.82	94.40	295.94	1.21	94.40
10016	636	183.40	99.50	0.60	16.70	161.67	-0.88	22.20	213.78	-0.62	38.90	223.78	-0.13	61.10	213.00	0.47	66.70	296.33	0.57	100.00
10017	455	110.29	99.70	0.00	0.00	-455.00	-99.00	16.70	192.00	-0.83	55.60	173.00	0.24	88.90	174.00	1.14	100.00	-55.00	-99.00	100.00
10018	393	88.21	98.50	0.60	0.00	-393.00	-99.00	11.10	175.22	-0.85	22.20	229.00	-0.33	16.70	341.00	-0.46	66.70	364.00	0.41	66.70
10019	555	196.41	97.90	2.50	16.70	130.67	-0.67	22.20	185.00	-0.43	38.90	186.11	0.07	44.40	268.00	0.16	88.90	231.11	0.86	61.10
10020	495	121.62	99.40	0.00	5.60	213.00	-1.75	44.40	73.00	0.22	61.10	138.00	0.51	100.00	-195.00	-99.00	94.40	265.00	1.11	77.80
10021	541	128.46	99.50	0.90	0.00	-541.00	-99.00	27.80	158.83	-0.46	44.40	205.00	-0.04	72.20	221.33	0.61	77.80	293.00	0.83	83.30
10022	802	227.80	99.50	0.90	11.10	238.33	-1.05	16.70	275.00	-0.77	55.60	151.67	0.21	44.00	287.33	0.06	72.20	274.17	0.55	88.90
10023	553	142.14	100.00	2.50	0.00	-553.00	-99.00	11.10	280.11	-1.27	33.30	223.00	-0.16	61.10	240.00	0.42	66.70	327.33	0.51	72.20
10024	408	96.01	2.60	1.20	0.00	-408.00	-99.00	11.10	207.33	-1.12	33.30	214.33	-0.15	77.80	232.00	0.71	77.80	332.00	0.71	72.20

	Non Stop-Signal Data				Delay SS-0 (MRT-0)		Delay SS-100 (MRT-100)			Delay SS-200 (MRT-200)				Delay SS-300 (MRT-300)		Delay SS-400 (MRT-400)			Delay SS-50	
Part #	MRT (ms)	SDRT	XO ID	NR	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR
10025	775	179.74	99.40	0.30	27.80	99.00	-0.55	77.80	-29.00	0.72	66.70	145.00	0.31	100.00	-475.00	-99.00	94.40	76.67	1.80	88.90
10026	583	142.42	98.40	0.00	16.70	138.00	-0.97	22.20	189.00	-0.62	44.40	191.00	0.06	72.20	209.00	0.64	77.80	293.00	0.75	88.90
10027	569	130.22	100.00	0.00	0.00	-569.00	-99.00	55.60	76.00	0.18	77.80	90.00	0.84	94.40	115.00	1.42	100.00	-169.00	-99.00	94.40
10028	417	96.98	98.90	0.60	5.60	171.00	-1.76	16.70	162.33	-0.64	61.10	163.22	0.38	83.30	226.00	0.76	72.20	346.44	0.55	72.20
10029	912	142.56	100.00	1.90	22.20	91.33	-0.64	44.40	125.67	-0.18	72.20	130.33	0.49	77.80	198.00	0.72	88.90	227.33	1.21	94.40
10030	475	120.81	100.00	0.00	11.10	135.00	-1.12	22.20	159.00	-0.49	61.10	149.00	0.42	94.40	169.00	1.08	77.80	318.00	0.68	100.00
10031	738	149.69	100.00	0.00	22.20	105.00	-0.70	38.90	142.00	-0.28	83.30	48.00	1.02	94.40	45.00	1.70	94.40	145.00	1.70	94.40
10032	578	115.69	99.70	0.30	16.70	104.83	-0.91	22.20	181.22	-0.70	72.20	118.00	0.71	72.20	218.00	0.71	88.90	271.89	1.11	94.40
10033	539	117.48	100.00	0.90	16.70	96.00	-0.82	27.80	139.83	-0.34	38.90	200.17	0.00	100.00	-239.00	-99.00	88.90	283.00	1.00	83.30
10034	668	158.33	99.50	0.90	22.20	102.33	-0.65	16.70	239.50	-0.88	50.00	195.50	0.03	77.80	174.33	0.79	77.80	274.33	0.79	100.00
10035	542	127.14	99.40	1.50	0.00	-542.00	-99.00	55.60	73.11	0.21	66.70	142.67	0.45	72.20	228.00	0.57	88.90	271.00	1.01	77.80
10036	719	134.88	98.30	0.30	22.20	67.67	-0.50	33.30	133.33	-0.25	66.70	153.00	0.35	94.40	82.67	1.61	100.00	-319.00	-99.00	100.00
10037	386	70.59	96.40	0.00	5.60	104.00	-1.47	16.70	134.00	-0.48	83.30	152.00	0.68	94.40	228.00	1.02	100.00	14.00	-99.00	94.40
10038	573	133.05	99.20	0.00	5.60	215.00	-1.62	22.20	197.00	-0.73	38.90	233.00	-0.25	50.00	292.00	0.06	66.70	317.00	0.62	83.30
10039	445	102.30	99.70	0.00	0.00	-445.00	-99.00	38.90	90.00	0.10	83.30	132.00	0.66	100.00	-145.00	-99.00	88.90	321.00	0.77	100.00
10040	450	97.14	99.40	0.00	5.60	195.00	-2.01	50.00	77.00	0.24	88.90	111.00	0.92	88.90	211.00	0.92	83.30	328.00	0.74	88.90
10041	739	116.18	100.00	2.50	5.60	191.44	-1.65	16.70	202.33	-0.88	83.30	99.00	0.87	83.30	199.00	0.87	94.40	211.67	1.62	100.00
10042	353	54.04	98.20	0.00	0.00	-353.00	-99.00	5.60	186.00	-1.59	27.80	230.00	-0.56	72.20	262.00	0.70	83.30	342.00	1.07	100.00
10043	679	136.32	100.00	0.30	16.70	108.67	-0.80	44.40	105.44	-0.04	66.70	147.00	0.39	83.30	182.67	0.86	88.90	252.78	1.08	94.40
10044	441	88.77	97.20	0.30	0.00	-441.00	-99.00	16.70	165.17	-0.73	38.90	210.00	-0.11	55.60	286.00	0.16	61.10	373.00	0.30	61.10
10045	772	138.51	100.00	0.30	11.10	139.11	-1.00	44.40	117.44	-0.13	55.60	185.00	0.11	72.20	230.00	0.51	94.40	172.00	1.65	100.00
10046	1703	522.76	98.70	12.70	61.10	-48.83	0.09	72.20	-77.56	0.34	66.70	91.67	0.21	72.20	122.44	0.34	88.90	-391.89	1.51	94.40
10047	490	118.17	97.60	0.30	16.70	89.33	-0.76	0.00	-390.00	-99.00	44.40	192.00	0.07	94.40	151.50	1.26	77.80	315.78	0.71	94.40
10048	524	180.07	97.90	0.00	22.20	109.00	-0.61	11.10	299.00	-1.11	44.40	184.00	0.09	55.60	231.00	0.38	77.80	262.00	0.77	94.40
10049	621	157.66	99.7	0.3	5.6	232.89	-1.48	38.9	116.39	-0.1	44.4	200	0	94.4	91.83	1.32	100	-221	-99	100
10050	455	99.00	99.40	0.00	11.10	139.00	-1.40	16.70	194.00	-0.95	66.70	148.00	0.53	100.00	-155.00	-99.00	94.40	285.00	1.16	94.40
10051	379	78.30	98.70	0.90	0.00	-379.00	-99.00	22.20	157.67	-0.74	44.40	202.00	-0.03	66.70	261.00	0.50	77.80	336.33	0.81	88.90
10052	498	212.15	96.80	1.50	11.10	187.56	-0.88	27.80	138.39	-0.18	55.60	133.78	0.31	61.10	215.06	0.40	61.10	315.06	0.40	66.70

	Non Stop-Signal Data				Delay SS-0 (MRT-0)		Delay SS-100 (MRT-100)			Delay SS-200 (MRT-200)			Delay SS-300 (MRT-300)			Delay SS-400 (MRT-400)			Delay SS-50	
Part #	MRT (ms)	SDRT	XO ID	NR	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR	SSRT	ZRFT	NR
10053	586	157.11	99.50	1.20	16.70	140.67	-0.90	38.90	124.11	-0.15	66.70	110.67	0.57	50.00	270.00	0.19	94.40	196.67	1.29	88.90
10054	667	184.68	99.50	0.60	11.10	213.78	-1.16	16.70	267.00	-0.90	38.90	271.78	-0.39	44.40	342.78	-0.23	55.60	380.11	0.11	61.10
10055	727	147.27	100.00	1.20	5.60	213.11	-1.45	27.80	183.11	-0.56	38.90	240.22	-0.27	77.80	196.11	0.71	88.90	199.67	1.36	94.40
10056	688	168.41	98.10	0.30	16.70	139.00	-0.83	33.30	132.67	-0.19	66.70	125.33	0.44	77.80	187.78	0.67	88.90	224.44	1.04	100.00
10057	473	119.36	97.60	0.30	5.60	202.33	-1.70	27.80	142.00	-0.35	38.90	208.39	-0.07	83.30	199.83	0.84	83.30	299.83	0.84	83.30
10058	860	131.60	96.80	3.40	27.80	68.06	-0.52	44.40	107.67	-0.06	61.10	156.72	0.33	88.90	167.11	1.01	100.00	-460.00	-99.00	100.00
10059	409	101.92	99.70	0.00	22.20	36.00	-0.35	11.10	182.00	-0.80	50.00	184.00	0.16	66.70	261.00	0.38	77.80	332.00	0.67	88.90
10060	590	126.41	0.30	0.30	5.60	216.39	-1.71	38.90	96.17	0.03	50.00	166.00	0.27	72.20	221.44	0.62	94.40	258.83	1.12	94.40
10061	496	102.04	99.20	0.00	16.70	108.00	-1.06	38.90	125.00	-0.25	77.80	116.00	0.82	61.10	262.00	0.37	83.30	294.00	1.04	77.80
10062	794	154.71	100.00	0.00	27.80	82.00	-0.53	50.00	95.00	0.03	72.20	116.00	0.54	88.90	118.00	1.18	83.30	253.00	0.95	88.90
10063	391	72.75	97.50	0.00	0.00	-391.00	-99.00	33.30	117.00	-0.23	72.20	172.00	0.38	100.00	-91.00	-99.00	88.90	313.00	1.20	94.40
10064	365	62.59	98.10	0.00	0.00	-365.00	-99.00	0.00	-265.00	-99.00	0.00	-165.00	-99.00	0.00	-65.00	-99.00	0.00	35.00	-99.00	0.00
10065	940	158.52	99.70	0.30	16.70	12.80	-0.81	61.10	54.00	0.29	83.30	73.67	0.80	94.40	70.78	1.45	100.00	-540.00	-99.00	100.00
10066	468	107.35	98.90	0.90	22.20	49.00	-0.46	50.00	83.00	0.16	66.70	146.00	0.50	83.30	214.00	0.80	83.30	314.00	0.80	83.30
10067	471	101.63	98.90	1.20	5.60	147.22	-1.45	27.80	127.00	-0.27	55.60	176.00	0.24	94.40	188.33	1.10	88.90	315.11	0.84	88.90
10068	590	183.43	98.90	0.30	22.20	75.22	-0.41	44.40	87.00	0.07	72.20	76.00	0.68	88.90	114.67	1.01	100.00	-190.00	-99.00	100.00
10069	466	111.67	99.70	0.00	11.10	111.00	-0.99	22.20	160.00	-0.54	38.90	209.00	-0.08	66.70	249.00	0.46	100.00	-66.00	-99.00	88.90
10070	491	115.38	99.70	0.00	11.10	128.00	-1.11	27.80	138.00	-0.33	61.10	153.00	0.41	83.30	196.00	0.90	88.90	280.00	1.04	94.40
10071	571	186.74	98.00	0.00	55.60	-32.00	0.17	38.90	141.00	-0.22	72.20	88.00	0.60	88.90	102.00	1.06	100.00	-171.00	-99.00	94.40
10072	804	158.14	99.70	0.00	27.80	89.00	-0.56	66.70	50.00	0.32	83.30	57.00	0.90	88.90	81.00	1.38	100.00	-404.00	-99.00	100.00
10073	488	118.60	99.50	0.30	5.60	238.33	-2.01	5.60	338.33	-2.01	27.80	242.00	-0.35	61.10	246.61	0.45	72.20	320.72	0.67	88.90